REINTRODUCTION OF THE GREATER BILBY

Volume I
A field guide

by Richard Southgate, Keith Bellchambers,
Kathryn Romanow and Shona Whitfield

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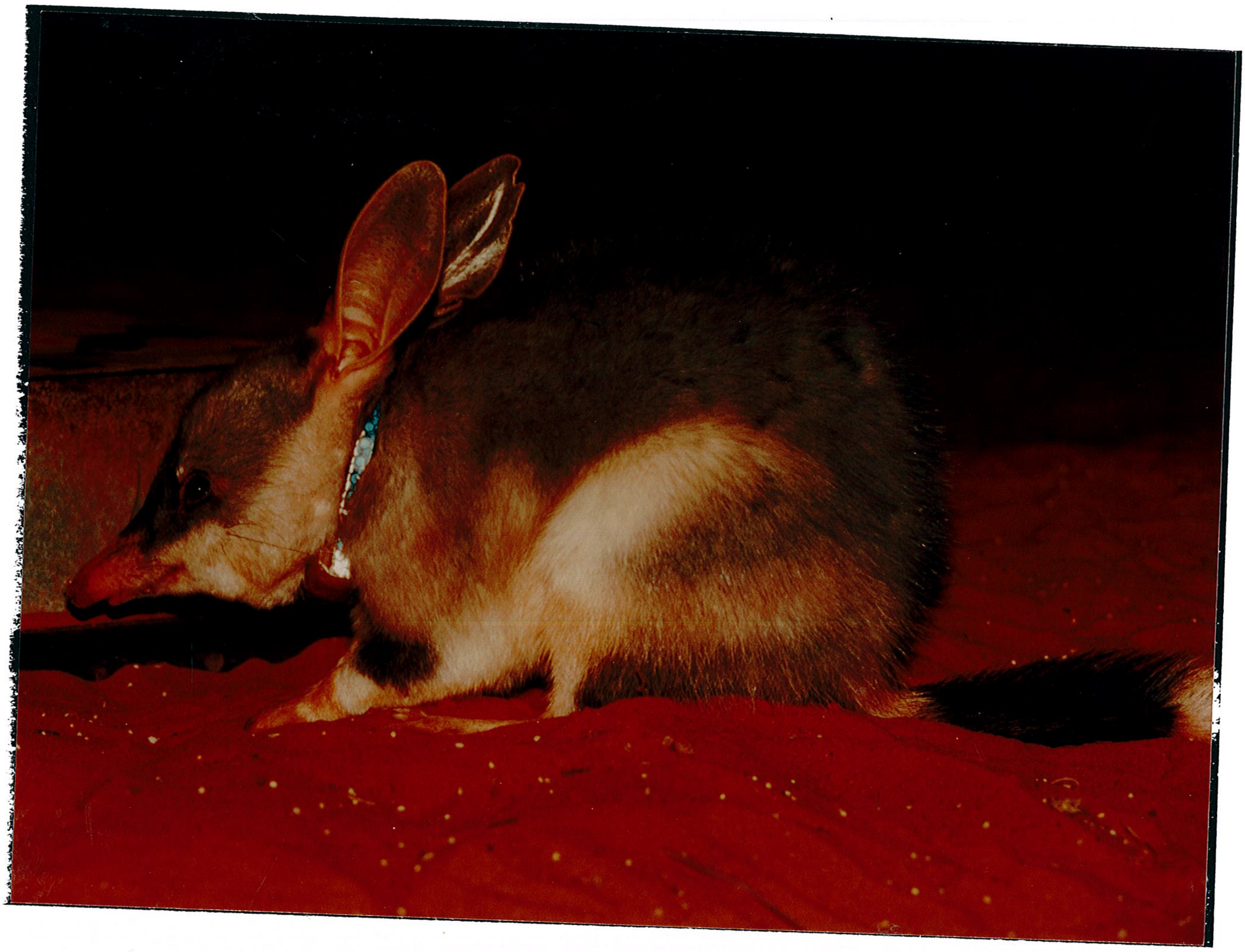

Plate 1 A reintroduced Greater Bilby *Macrotis lagotis* sporting a radio-transmitting collar resting near a seed hopper in Watarrka National Park.

Overview

This document provides a comprehensive and practical reference to the reintroduction of the Greater Bilby *Macrotis lagotis*. The reader is presented with a background in bilby ecology, procedures to transfer constrained animals to a free-range existence and the principles for collecting information relevant to the conservation of the species. It is the result of information obtained from a 10 year captive breeding program, a three year study of the distribution and abundance of the bilby in central Australia (Southgate 1987), four years of research developing re-introduction procedures and a growing body of related scientific research.

The bilby is a species of bandicoot currently under threat of extinction. Prior to the arrival of Europeans the species was widespread and common throughout arid Australia. Now it is severely reduced in distribution and possibly still declining. It is part of a suite of species which have disappeared from the arid zone of Australia in the past 50 years. The bilby has managed to persist only in relatively unproductive parts of its former range where stock, rabbits and foxes are absent or in low abundance. There is no single cause of decline and it is evident that bilby populations are vulnerable to predation from introduced predators and habitat degradation from introduced herbivores. We have little information about the conditions and the interactive processes affecting the fate of a bilby population in the field. Our conservation goal for this species, stated simply is to **reverse its decline by securing its remaining distribution and facilitate the expansion of its current range.** It is assumed that the committment to this process would continue until the species is placed in a position where it could survive for thousands of generations (in the order of 10 000 years).

Over the past 20 years there has been growing concern about the extinction of species and much has been written about the management of small populations and factors influencing the risk of extinction. A whole facet of science has emerged under the banner of conservation biology (Soule 1980; Frankel and Soule 1981; Stonewald-Cox *et al.* 1983; Soule 1986) and restoration ecology (Jordan *et al.* 1987). The reintroduction of rare or threatened species falls squarely into this arena because we are generally dealing with small populations and trying our best to identify, remove or control hazards and restore populations to previously occupied precincts.

Within the scientific community there is also concern that effort spent to secure individual species is not achieving conservation of biodiversity. Some argue we should pay less attention to rare or threatened species and instead, concentrate on identifying and conserving areas of biodiversity or use functional groups of organisms to determine how to manage or conserve landscapes and ensure the long-term persistence of biota (Noss 1990; Walker 1992).

It is within this spectrum of viewpoints we must develop a rationale for a species' reintroduction. A common thread does exist. Conserving either a species or the function of an ecosystem requires information about the structure, composition and processes which shape the system. The approach advocated throughout this document has been to use reintroduction as a tool to learn about the requirements of a bilby population and condition of a recipient environment. Because of the vacuum created by the almost complete disappearance of medium-sized native mammal species from the arid zone of Australia, it is virtually impossible to examine the extent of ecosystem dysfunction without an autecological approach involving reintroduction of species such as the bilby.

The possibility for researchers and managers to develop a successful conservation strategy for the bilby is possibly less daunting than for many other similar sized arid mammal species. There are still sizeable populations of the bilby occupying a range of habitats. These populations provide us with genetically variable stock for captive breeding purposes and the chance to study the conditions which permit persistence in the wild. However, the populations are vulnerable and possibly in decline and there is an urgency to act before the situation deteriorates further, otherwise we could be presiding over the extinction of yet another species.

The bilby provides the ideal "flagship" species for conservation and sustainable land use issues in the arid zone. Its former distribution embodied the arid zone, its decline has indicated a sensitivity to several processes affecting other threatened species, and the intended expansion of its range and conservation of widely scattered remnant populations will require careful consideration of European and Aboriginal land use including the relevance of national parks, mining, tourism, the use of fire and management of feral animals and stock.

A two pronged attack is proposed:

1. conduct monitoring of the wild populations to determine the status of wild populations and the habitat conditions which are most favourable; and,
2. implement reintroduction programs in a range of habitats previously occupied by the bilby to determine the favourability of these habitats and the extent of management required to make these habitats suitable for occupation.

This document is concerned primarily with reintroduction. Nevertheless, the objectives and design of a reintroduction program should be dependent upon the status of the extant wild population and the information derived from these populations.

The reintroduction of a species *per se* is a simple concept but a complex task. It provides a powerful tool to rapidly obtain the knowledge of the factors which limit a species because it is essentially a form of transplant experiment (Krebs 1978; Begon *et al.* 1986). However, the process is seldom used effectively and has been relatively unsuccessful in solving conservation problems. Most reintroduction programs of rare and threatened species have failed to establish a self-sustaining population, despite great effort and expense (Griffith *et al.* 1989; Short *et al.* 1992). Such instances are viewed as failures or embarrassments and often remain unreported which is extremely counter productive. It is our view that a reintroduction program fails only when no useful information is produced to assist in the long term conservation of a species and suitable habitat. This situation may arise either when a reintroduced population declines or prospers.

The emphasis throughout these documents has been to provide procedures and a framework for the reintroduction of the bilby to ensure scientific principles are applied whenever animals are released. Unless we can describe why the size and the composition of a population changed at a particular locality, we are no further advanced in our goal to conserve the species. Therefore, the immediate goal of reintroduction programs should be, to **improve our understanding of the conditions which permit a bilby population to survive.**

In this sense, the approach we advocate differs significantly from the reintroduction protocol outlined by the IUCN (1987). The IUCN recommends the reintroduction of a species should not proceed if the causes of a species' extinction remain unremedied and should only take place when the habitat requirements of the species are satisfied. We argue that for most threatened species the habitat requirements are poorly known. The only means to derive this information is to examine the response of the threatened species to a recipient environment through reintroduction programs.

A number of principles have been developed to guide the process of reintroduction. A bilby reintroduction should be:

- hypothesis driven;
- developed with an experimental design using replicated independent sample units and controls where appropriate;
- using the species generation time and home range/dispersal characteristics to determine minimum monitoring duration and reintroduction area;
- producing information comparable to that obtained at another time and

location; and,

- directed by decision rules which determine the intensity of population and environmental monitoring and when the program should be terminated.

In the case of the bilby the minimum sample unit size should consist of five animals (two male and three female); intensive monitoring should be conducted for at least 24 months and the minimum area used for reintroduction under free-range conditions should be at least 25 km^2.

Bilby reintroduction into Watarrka National Park was initially successful, with numbers increasing in response to good seasons, but then crashing, probably as a result of predation as predator numbers increased. Predator control was not effective in producing conditions which were acceptable to the bilby population. The challenge is to test the applicability of these data at other release sites.

Priorities for reintroduction and research on the bilby include determining the growth of released populations:

- in areas where existing conditions, facilities and management provide a reduction in predator density or the exclusion of predators; and,
- in areas where rabbits and stock are absent or managed at low density.

We believe the conservation goal for the bilby would be most rapidly achieved if reintroduction and research could be coordinated at a national level. This approach would provide a degree of control over the methods used for a re-introduction program and the information produced, resulting in a more dynamic and useful conservation strategy. It is proposed that any reintroduction of the bilby be part of a Recovery Plan and administered by a Recovery Team as proposed by the Australian Nature Conservation Agency.

Such a program would be costly and in competition for funding with other equally important conservation programs. With planning and publicity it is envisaged that reintroduction could be promoted and become an attractive and beneficial activity for a wide range of land users including pastoralists, Aboriginal groups and non-government organisations, in addition to the Territory, State and Federal government authorities. A successful program will require support from the broader community. It is an advantage that the bilby is a striking and charismatic species, and that individuals are relatively robust and easily handled.

The proposed approach has wide-ranging implications. If it is not possible to successfully reintroduce or translocate the bilby then there is little hope for the re-establishment of other bandicoot, wallaby, native cat and possum species which previously shared the habitat and have now declined. Over 70% of Australia is arid and semi-arid but to date it has received scant attention. Information generated from the proposed work will add significantly to our understanding of its functioning, the ecology of its endangered fauna and the management of its biotic resources.

About this document

The document has been separated into three volumes because the information contained within each volume is largely relevant to different audiences. It is hoped that the format of the document will provide easy access to information and that the continuity between the three volumes will facilitate and stimulate discussion. Some of the principles and information have been repeated in each of the volumes to achieve coherence.

Volume I provides a practical guide for the transfer of animals from a constrained to a free-range existence and the associated monitoring. It has been written for people in the field with a "hands-on" role in the reintroduction and management of a bilby population. It contains the Overview, Background and goals and Reintroduction procedures and Appendices and the references relevant to the volume. Protocol and proformas are provided in the appendices to assist in the collection of information.

Volume II contains information relevant to the program planning and analysis of information. It has been written mainly for those behind a desk making decisions about the species' conservation priorities and how best to fund and coordinate the necessary research and management activities. It contains Program design and Ecological methodology and a repeat of the Overview,

Volume III describes the characteristics of a reintroduced bilby population and the release environment. It contains the main body of information on the bilby in 10 Boxes plus a repeat of the Overview. The information was collected using techniques outlined in **Volume I** at Watarrka National Park and analysed using procedures described in **Volume II.**

The relationship between problems, goals, information and opportunities to acquire information on a species using reintroduction techniques is shown schematically in **Fig. 1.** It is expected that the known range of acceptable and unacceptable conditions for the bilby will need to be amended following additional reintroduction and research. These will alter the goals and perceived problems (Background and goals) facing the species which will change the priorities for futher reintroduction and research (Program design). This may alter the type of information required to solve the conservation problems (Ecological methodology) and therefore affect the monitoring procedures implemented at a reintroduction or research site (Reintroduction procedures)

Background and problems

Problem definition: The bilby population is declining and already severely reduced in distribution.

Goal formulation: Reverse decline, secure and expand range

Model formulation: Reasons for decline; known acceptable conditions

Program design

How can we most effectively achieve the goals described in the Backgound and goals section?

A national strategy and scientific approach:

- Formulation of relevant specific hypotheses
- Collation and integration of data produced by applying Reintroduction procedures and Ecological methods

Ecological methods

What type of information is useful? What information is required to address problems outlined in the Program design section?

. Habitat characteristics; known suitable conditions and known limiting conditions

. Characteristics of bilby fecundity and survival

Reintroduction procedures

How can we most effectively produce information required in the Ecological methods section?

. Procedures for site selection and implementation of a reintroduction program

. Procedures to acquire information

- population monitoring
- environmental monitoring

Fig. 1. The relationship between problems, goals, information and opportunities to acquire information in a reintroduction program.

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Background and goals

1.0 Introduction

There is developing concern about the rate of decline and extinction of species; the reduction in biological diversity of the planet is the most basic issue of our time (Soule 1980). The situation in arid and semi-arid Australia is already particularly bleak with 25 native animals having severely declined or become extinct since European settlement (Burbidge and McKenzie 1989; Morton 1990). The bilby has declined severely and may become extinct if we remain complacent.

For those unfamiliar with the bilby, a brief description of the animal is provided. The main theories proposed to explain the decline of Australian desert dwelling species are described and then discussed in relation to the decline and current distribution of the bilby. A synthesis of the problems and questions which we must now tackle and possibly address through reintroduction programs are presented and finally, some of the terms and concepts which recur throughout this document are defined.

1.1 What is a bilby?

The Greater Bilby is a type of bandicoot and the only surviving member of the family Thylacomyidae (Superfamily: Perameloidea) (**Plate 1**). The Lesser Bilby *Macrotis leucura*, the other member of the family, has not been recorded alive for 60 years (Johnson 1989).

The extant bilby is a terrestrial, nocturnally-active marsupial about the size of a rabbit. It is sexually dimorphic with adult males (1400-2500 g) attaining twice the mass of adult females (700-1200 g). The species is omnivorous, feeding primarily on seeds, bulbs and invertebrates, excavating much of this food from the soil. Individuals dig burrows sometimes more than 2 metres deep, which are used for rest and shelter during the day and intermittently at night.

Individuals commonly occur singly or in small groups of 2-4 animals; sign of digging for food and burrowing activity of these animals can extend over an area of 10 - 50 ha (Philpott and Smyth 1967; Watts 1969; Southgate 1990c). Occasionally larger groups may be encountered and evidence of their activity can extend over several square kilometers (LeSouef and Burrell 1926; Southgate 1990c). Males, females and juveniles occupy overlapping home ranges.

Johnson (1989) and McCracken (1983; 1986) provide a more detailed description of bilby morphology, behaviour and physiology. Additional information regarding social organisation, habitat use and diet will be provided in the information Boxes contained in **Volume III**.

1.2 What has happened to the bilby?

The bilby was part of a diverse arid and semi-arid mammal fauna. Over 35% of the mammal species in the faunal assemblage have vanished, predominantly from a group referred to by Burbidge and McKenzie (1989) as critical weight range (CWR) species (35-5500 g,). Of the five bandicoot species and five small kangaroo species present before European settlement, only the bilby is still relatively widely distributed. The others are now severely restricted in range, located only on islands off the mainland or extinct. In this sense the bilby is one of the few mainland, arid-dwelling, medium-sized mammals remaining on which to conduct substantial manipulative research.

At the time of European settlement the bilby was distributed over 70% of the Australian mainland, occupying the arid and semi-arid country from the Great Dividing Range to the West Australian coast (**Fig. 1.1**). The decline in bilby numbers is reported to have begun as early as 1850 (Krefft 1866), but the most rapid decline occurred between 1900 and 1940. The bilby now occupies about 20% of its former range and is restricted to some of the most arid parts of this, most of which is unsuitable for extensive pastoralism. Decline of the species was evident on pastoral land between 1970 and 1985. It is uncertain whether the decline in distribution of this species has halted (Southgate 1990a).

1.3 Proposed reasons for the decline

The factors causing the decline of the bilby and similar sized native animals in arid Australia have been widely debated (Finlayson 1961; Southgate 1987; Burbidge *et al.* 1988; Burbidge and McKenzie 1989; Morton 1990). There is still a diversity of opinion and shifting attitude surrounding the processes which are considered primary to the loss of species. Three main hypotheses have emerged:

- Change of burning regime
  Traditional "small mosaic" burning practiced by Aborigines favoured the CWR species. With European settlement this type of burning has ceased, causing habitat to become unsuitable.

- Introduced predators
  The Red Fox *Vulpes vulpes* and Feral Cat *Felis catus* were both introduced to Australia before 1900. Predation by these species has caused the decline of CWR species.

- Pastoralism and rabbits
  Stock and the introduced European Rabbit *Oryctolagus cuniculus* have degraded key habitats of the CWR species. The remaining habitat is mostly unsuitable for CWR species.

However, following a survey of bilby distribution and abundance, Southgate (1990a) suggested that no single factor was responsible for the species' decline. The relative effects of fire, predators and competitors varied between locations and were probably interacting:

- Fire was found to be an important factor in reducing ground cover and promoting certain plant resources at bilby colonies, especially in the north of the bilby's current range. However, the bilby was also found to occupy habitat where fuel was inherently scarce and fire was extremely infrequent; plus, it was persisting in areas where traditional Aboriginal burning practice had largely ceased.

- The Feral Cat distribution presently overlaps and has overlapped with the current range of the bilby for at least 100 years. In contrast, the bilby disappeared as the Red Fox became established (Jones 1924; Finlayson 1961) and bilby distribution now associates with an absence or scarcity of foxes in the southern part of its range. However, the bilby has also declined in the northern part of its range in areas where the fox was absent or in extremely low density.

- The bilby's current range corresponds best with an absence of pastoralism and rabbits, but, the bilby persists with cattle on some pastoral leases and also with rabbits (at low density) in certain habitats.

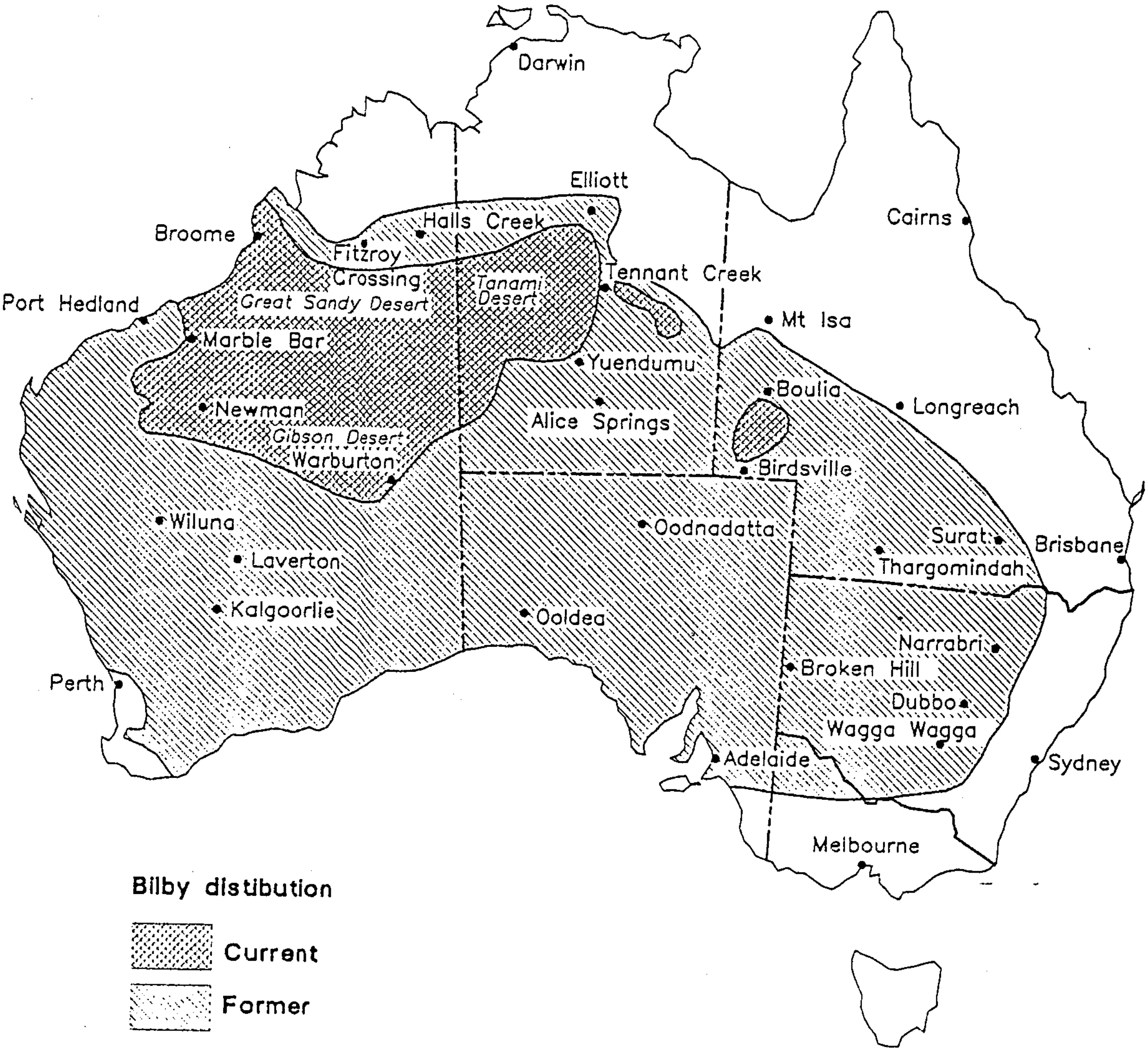

Fig. 1.1 Distribution of the Greater Bilby

1.4 What is needed?

Clearly, no progress will be made from further broad correlation. With several perturbing factors recognised it is now necessary to collect empirical data to assess the relative importance of each and their interactive effects.

It is not surprising that there are differences of opinion and uncertainty surrounding the decline of central Australian fauna. There is a meagre understanding of the processes which affect CWR species and little data available to improve our understanding of the situation.

The sparse ecological knowledge base in the arid zone of Australia is related to the short time Europeans have been present, the speed at which the landscape has altered and the general scarcity of ecologists. The scientific knowledge on mammals prior to 1960 rests primarily on the efforts of the Horn Expedition (Spencer 1896) and Finlayson (1961). While broad mapping of soils and landform now exist, the distribution of much of the biota is explained by more subtle patterns of variation (Stafford Smith and Morton 1990). On a world scale, Australia is unique because of the infertility of soils and unpredictability of precipitation. Many of the generalisations formed in other arid regions of the world are not applicable to Australian conditions (Stafford Smith and Morton 1990) leading Westoby *et al.* (1989) to suggest existing research and management practices in arid Australia are largely inappropriate and should be developed in accordance with the variability of landscape and climatic conditions.

Equally important to the success of conservation and restoration effort is understanding the severity and reversibility of degradation caused by damaging processes. Is the damage easily reversible or has degradation resulted in a new dynamic regime which cannot be easily reversed? The answer to this question determines the appropriate strategy with which to address particular ecological problems and options for management. These two scenarios require fundamentally different approaches (Friedel 1991; Dexter 1992).

Clearly a serious situation exists. On the one hand, there is an urgency - the survival of the bilby is at risk; it is possibly still declining and its habitat is prone to drought and further invasion by feral animals or weeds. On the other hand, with scant data and a rudimentary understanding of the ecological issues involved we cannot afford to cut corners. We need to be careful about the questions we pose, the procedures we use and the underlying assumptions we make. Criteria to select and manage habitat for the conservation of the bilby still needs development.

Reintroduction of species like the bilby provides a tool for obtaining the desired information and understanding - the acid test is whether reintroduced animals thrive in selected and manipulated habitat. There are several key areas of concern:

- The levels of predator, rabbit and stock activity and the types of fire regime which permit a viable population of the bilby to survive need to be determined.

- The long term effects of the perturbing factors must be considered. Habitat may remain unsuitable for recolonisation through damage or degradation of soil and vegetation long after original disturbance has occurred; for example, the availability of food may be affected.

- The effect of environmental variability and stochasticity on the viability of different sized subpopulations and metapopulation configurations.

- The role of management to enhance population survival at particular localities must be thoroughly examined.

An experimental approach with suitable controls and replication is required to investigate the impact of specific factors. Sequential sampling of a released population may be used to more clearly define a set of conditions which make habitat suitable for occupation. **Volume II** discusses these issues in greater detail.

1.5 Defining re-establishment, reintroduction and translocation

It is useful to clarify what is meant by re-establishment, reintroduction and translocation. The IUCN (1987) defines reintroduction broadly as "the release of a species of animal or plant into an area in which it was indigenous before extermination by human activities or natural catastrophe". We felt it necessary adopt a more specific use of terminology to differentiate the source of animals used in a release and the intent of a particular program. The ultimate goal is to successfully re-establish a bilby population. Reintroduction or translocation is the starting point for a re-establishment program but not all reintroduction or translocation programs will necessarily become fully fledged re-establishment programs. The primary objective of reintroduction and translocation programs should be to provide information which will help attain the goal of re-establishment.

1.5.1 Translocation

Translocation is the moving of wild-caught animals for release into the wild at a second site (Kleiman 1989). This process has the advantage in that the animals are already proven survivors under wild conditions; no training or rehabilitation is necessary; and, there is no likelihood of transporting diseases from captivity to the wild (Chivers 1991). Conversely, the process of capture and transporting the animals may stress and damage individuals. Some injuries to the bilby would be difficult to detect unless individuals were monitored in captivity before release.

1.5.2 Reintroduction

Reintroduction involves the release of captive-bred animals or those born in the wild but subject to a captive existence (Kleiman 1989; Stanley Price 1989). Captivity may reduce the fitness of individuals by compromised selection pressure leading towards gradual domestication (Stanley Price 1989; Ralls 1993). Preparation may be required to acclimatise or rehabilitate individuals before they are released to improve performance and survival. However, the use of captive-bred animals does provide control over the availability, genetic composition and health of the founder stock. This is particularly valuable if a primary aim is to determine the impact of the environment on released individuals.

1.5.3 Re-establishment

A species can be considered to have been successfully re-established when a viable, self-sustaining population exists (Griffith *et al.* 1989) In other words, the population needs to have reached a stage where its reproductive success will enable it to persist through environmental perturbations and to prosper in the intervening period. It may take many years to assess whether a population can persist through the full range of environmental extremes. Bold claims of the success of a program must, therefore, be viewed with caution!

Factors affecting the long-term survival of a species still require considerable research. "Viable" and "sustainable" population sizes are largely unknown for many species, especially those that are rare. However, the need to define and consider these attributes acts as a focal point for research into threatened species.

1.6 Study localities

The procedures and techniques outlined in this document were developed using captive-bred animals during a program to reintroduce the bilby at Simpsons Gap National Park (SGNP) and Watarrka National Park (WNP) in the Northern Territory (**Fig. 1.2**). Both Parks are well within the limits of the former distribution of the bilby and support a variety of habitats likely to have been used by the species. However, definite records of the bilby occurring in the region are few. Spencer (1896) recorded the hand sign used by Aborigines for the bilby at Tempe Downs (adjacent to WNP) and the species was recorded in the general vicinity of Alice Springs.

The climate at SGNP and WNP is similar, with cool winters and extremely hot summers (**Fig. 1.3**). Zero or sub-zero temperatures may be recorded in the months May to September with minimum temperatures as low as -6^{0}C. Maximum summer temperatures may exceed 44^{0}C and commonly range between 35-40^{0}C (Bureau of Meteorology data for Tempe Downs and Alice Springs).

Rainfall may vary significantly between years with brief, exceptionally wet periods, interspersed with lengthier periods of average or below average rainfall. The average annual rainfall for WNP is approximately 240 mm and 300 mm for Alice Springs; in both areas rainfall is generally distributed throughout the year with a slight peak in summer. **Volume III** contains more climate information for WNP.

1.6.1 The captive breeding colony.

A captive bilby breeding colony was established in Alice Springs. From three animals wild-caught in April and two in August, 1979 (2 female, 3 male) four individuals were bred in captivity in the first twelve month period. A further wild-caught male and female were added in April, 1981 and the captive population expanded from 27 in July, 1981 to 51 individuals in April, 1982. An additional 11 wild caught animals (6 female and 5 male) have been added to the colony since this time. All the individuals were captured in the Tanami Desert (except one which originated from Warburton) with the assistance of Aboriginal people from Yuendumu, Willowra and Nyirripi communities.

The capacity of the captive breeding facilities now stands at about 30 animals using facilities at the Arid Zone Research Institute (AZRI) and yards at SGNP. An additional breeding colony with similar capacity has been established at the Western Plains Zoo, Dubbo. Several other zoological institutions maintain small numbers of the bilby for display purposes.

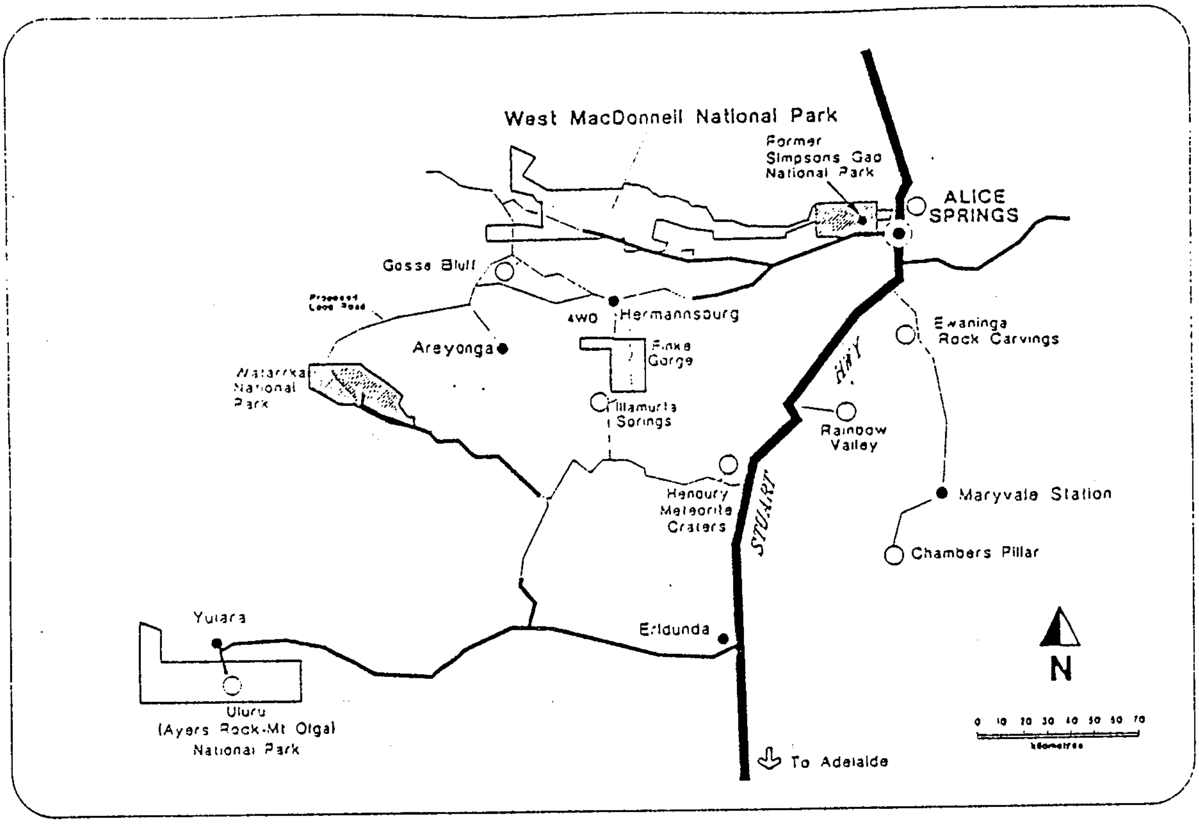

Fig. 1.2 Location of Simpsons Gap National Park and Watarrka National Park.

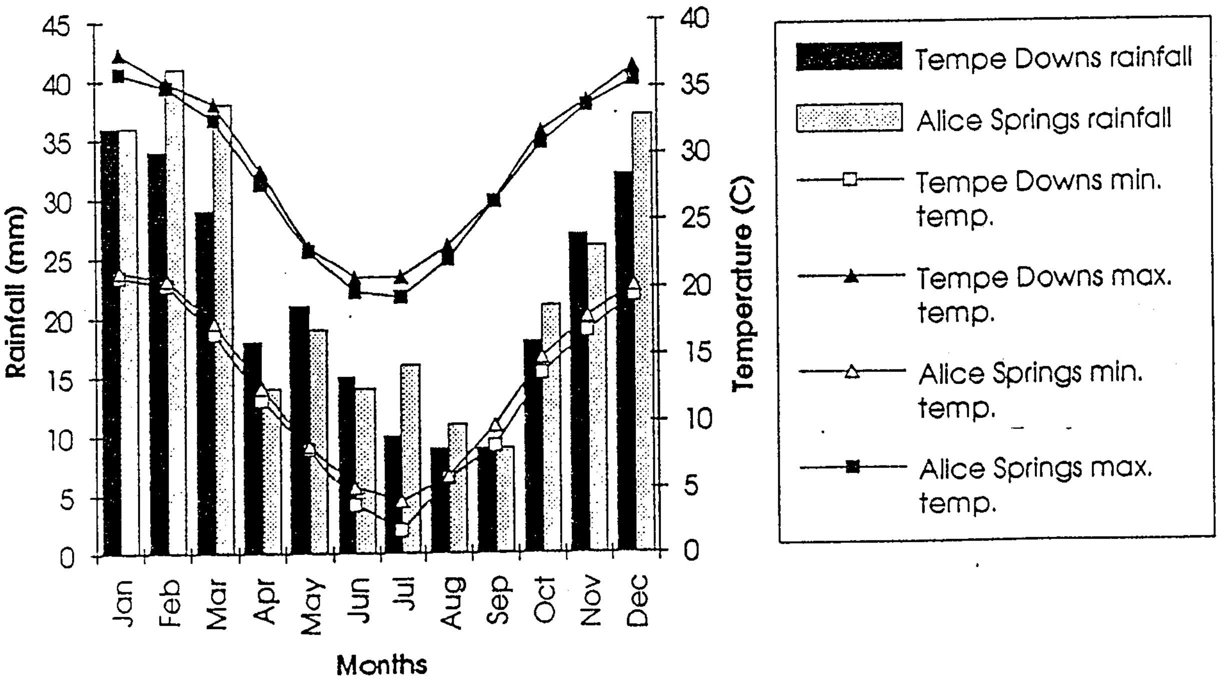

Fig. 1.3 Mean and maximum monthly temperature and mean monthly rainfall records for Tempe Downs and Alice Springs.

1.6.2 Simpsons Gap National Park (SGNP)

SGNP is situated 15 km west of Alice Springs and covers an area of 308 km^2 (**Fig. 1.4**). The Park is bounded by pastoral lease to the north and south, Alice Springs town boundary to the east and Aboriginal land to the west. The four attempts to re-establish the species over a period of eight years provided promising results but none of the populations prospered (**Table 1.1**). Data on bilby fecundity and survival and the associated environmental conditions at the time of these releases are scant because of inadequate monitoring effort. Only information from releases S3 and S4 is included in this document.

1.6.3 Watarrka National Park (WNP)

At the end of 1987 WNP was chosen as an alternative reintroduction site to Simpsons Gap National Park. The Park is situated 330 km by road south-west of Alice Springs and includes the tourist attraction of Kings Canyon. It was once part of Tempe Downs Pastoral Lease and covers an area of 340 km^2 (**Fig. 1.5**). It is currently bounded by a grazing lease on the southern and eastern boundaries and Aboriginal land on the remainder. The Park offered:

- the potential to conduct predator monitoring and control;
- a range of habitat types including sand plain with spinifex habitat;
- reasonable accessibility from Alice Springs and a network of roads within its boundaries;
- the possibility of support from resident ranger staff;
- areas where rabbits were in relatively low abundance; and,
- the potential to implement a fire management program.

Animals were introduced to pens situated in Hope Valley (site HV) in March, 1988. A separate release site was established near the Ranger Residence (site RR) in November, 1990. Most of the information discussed pertains to the Hope Valley site. The RR release was used mainly to test release procedures and the response of animals to release. The majority of the information collected was obtained before February, 1991. Information on some aspects of the study was collected until January, 1992. A more detailed description of the study area at WNP is provided in **Volume III**.

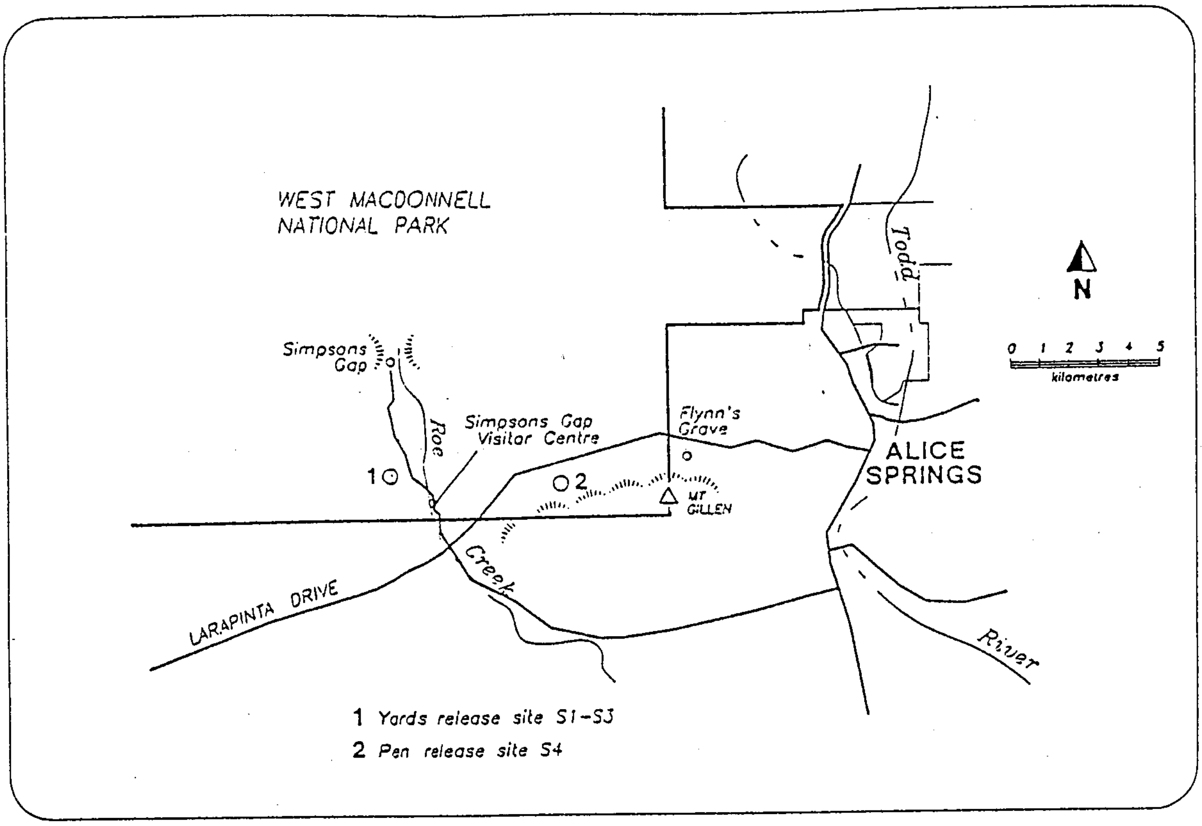

Fig. 1.4 The main study areas in Simpsons Gap National Park

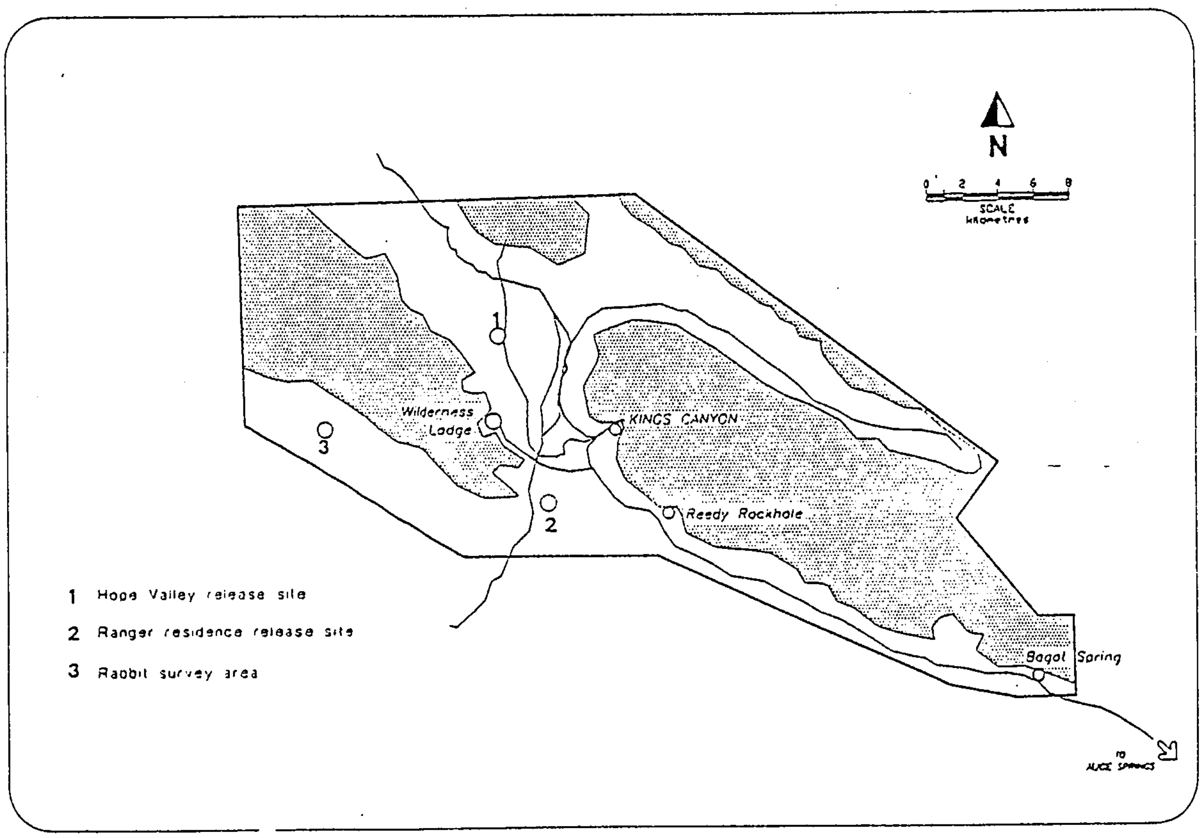

Fig. 1.5 The main study areas in Watarrka National Park

Table 1.1 Almanac of bilby releases at SGNP and WNP indicating the type of information collected during each release.

					Investigations undertaken:			
Region	Date	Release	Location[1]	Animals	Diet analysis	Vegetation assessment	Predator assessment	Colony survival[2]
SGNP	8.1982	S1	Yards	18				7+
	7.1983	S2	Yards	14	x			6+
	6.1985	S3	Yards	5	x			6+
	4.1987	S4	Pens	4	x		x	3
WNP	4.1988	W1	HV	4	x	x	x	27
	10.1988	W2	HV	4	x	x	x	24
	1.1990	W3	HV	2	x	x	x	7
	11.1990	W4	HV	5	x	x	x	1
	11.1990	W5	RR	5		x	x	8

1 See Fig 1.4 and 1.5.
HV = Hope Valley and RR = Ranger Residence Release Site

2 Estimated longest period of time (months) that individuals of the released animals survived.

Reintroduction procedures

2.0 Introduction

From a biological perspective, the successful reintroduction of a species requires:

- a source of animals for release (either from a self-sustaining captive-bred or wild population);
- effective reintroduction procedures to transfer animals from a constrained to a free-range existence; and,
- a site for release with favourable habitat.

There are also socio-economic or non-biological requirements for implementation of a reintroduction program such as political, logistic and administrative aspects which can not be neglected (Kleiman 1989; Stanley Price 1989; Gipps 1991).

Because favourable bilby habitat can not yet be confidently selected or effectively managed, we argue that bilby reintroduction should be used as a tool to obtain the desired information. When the habitat requirements of the species are well understood and favourable habitat can be identified or created prior to the release of animals, reintroduction may then become a restoration tool to increase the number of sub-populations or increase the number of individuals within a population.

This part of the document describes the procedures necessary to establish captive-bred animals in the field and discusses how to monitor the released population and its environment. An experimental approach is stressed because this method has produced the most reliable knowledge in ecology and science in general (Underwood 1990; Armstrong *et al.* 1994).

The rationale for the design of the bilby reintroduction program has been to minimise the cost of infrastructure and expensive capital items and rely on the information obtained from monitoring to guide program direction and development. For example, there is no need to construct predator-proof pens if predator activity levels fall in line with those prescribed. The set of conditions required to sustain a bilby population will gain accuracy as the knowledge base expands.

Reintroduction procedures and activities may be separated into a number of phases and tasks as shown in **Fig. 2.1**. The importance of the information generated increases as each new phase is reached and with each addtional reintroduction program, this information needs to be used to improve the site selection criteria and management procedures.

Protocol and pro-formas are provided in the appendices to assist the collection of information. The data collected by following these guidelines should be suitable for analysis using the procedures outlined in **Volume II**.

Phase 1 p 15

- Clearly determine the design and objectives of the reintroduction program
- Conduct site selection and suitability assessment of a proposed location

Phase 2 p 23

- Trapping, handling and transporting animals
- Establishment of animals in temporary enclosures and monitoring of their health
- Release of animals from temporary enclosures

Phase 3 p 33

- Monitoring the fate, dispersal and diet of the reintroduced population
- Monitoring the characteristics of the surrounding environment

Fig. 2.1 Phases of a reintroduction program.

Phase 1 Program objectives, feasibility and site selection

2.1 Objectives and program feasibility

It is essential to have the commitment to a reintroduction program and its objectives clearly established before commencement. The role of bilby reintroduction has moved beyond determining base-line information on the species and the effectiveness of release procedures. Although improvements in these departments may be made, the overwhelming priority lies in improving our ability to identify favourable habitat and effectively secure and maintain these features. Bilby reintroduction programs need to be designed to generate information and to test ideas or hypotheses concerning the decline of the species and the suitability of habitat.

2.1.1 Program logistics and operational rules

At the outset, the amount of financial and personnel commitment and the physical characteristics of the proposed reintroduction site will largely dictate the specific objectives of a program. A bilby reintroduction program needs to be monitored over at least a two year period before the feasibility of re-establishing a population at the locality can be stated with confidence.

The objectives of a program may alter substantially once the habitat suitability and the amount of management required to sustain a population at a particular locality have been determined. The results may show no management is required. Alternatively, if the conditions at a selected site need to be improved and maintained, it signifies that commitment to the program may be required indefinitely. Termination of the program may be necessary if the management required to sustain a population can not be justified.

For each program, a sequence and set of operational rules will be needed to regulate the implementation of the program and the administration of monitoring and management. A flow diagram showing the operational rules appropriate for Phase 1 is presented in **Fig. 2.2**.

Assistance in designing a reintroduction program will be provided by the Bilby Recovery Team (see **Appendix 4.1, Volume II**). The intended role for this team is to update information on reintroduction procedures and site pre-requisites, collate information derived from reintroduction programs and coordinate and assess prospective re-establishment programs.

PHASE 1: SITE SELECTION AND PROGRAM DESIGN

QUESTION 1: **HAVE THE OBJECTIVES OF THE PROGRAM BEEN FORMULATED AND HAS THE BILBY RECOVERY TEAM BEEN CONTACTED?**

YES Go to Question 2.
NO **Establish clear objectives for the program and consult the Bilby Recovery Team.**

QUESTION 2: **HAS THE REINTRODUCTION PROGRAM BEEN APPROVED BY THE RELEVANT STATE OR TERRITORY CONSERVATION AUTHORITY, THE BILBY RECOVERY TEAM, THE LOCAL SHIRE OR COUNCIL AUTHORITIES AND NEIGHBOURS?**

YES Go to Question 3.
NO **Consult relevant authorities and land users**. Check that the program does not contravene by-laws or will be unlikely to receive fininancial and government support.

QUESTION 3: **HAS THE REINTRODUCTION SITE BEEN ADEQUATELY MONITORED AND MET ALL THE PREREQUISITES?** (see section 2.2)

YES Go to Phase 2.
NO **Consult Bilby Recovery Team, need to select a suitable reintroduction site.**

Fig. 2.2 Operational rules for Phase 1 of a bilby reintroduction program.

2.1.2 The experimental unit

As outlined previously, each reintroduction tests whether the surrounding habitat is suitable for the released individuals and provides a very powerful means of obtaining information about the factors which limit a species. Because so little information is available on the environmental conditions which influence a bilby population's growth, it is prudent that a reintroduction program be structured to include monitoring of the population and the habitat.

The reintroduction of animals is, in fact, a type of transplant experiment; if a group of animals receives a similar set of environmental conditions we can define it as a **sample unit**. A group of animals released at a particular locality potentially forms one of these units.

In biological sciences it is not sufficient to rely on the observations and measurements from one sample unit (Krebs 1989) because initial or inherent variability (i.e. genetic variability, chance or ill health among individuals) within the unit may lead to a distortion of results and conclusions. To avoid such problems sample units need to be replicated, providing a type of insurance for the experiment. This means there should be at least two independent groups of animals released and monitored at any one time. These groups need to be exposed to a similar set of environmental conditions.

The discussion in this part of the document refers to the resources required to re-establish two sample units in the same vicinity and test the favourability of the release environment. **Table 2.1** indicates the minimum prerequisites and desirable habitat conditions for a bilby reintroduction study site.

2.1.3 Number of animals for release

The number of animals for release is a compromise of the following considerations:

- it is prudent to release a few animals to test site conditions before jeopardising many;
- it may be unmanageable to monitor many animals; and,
- the number of animals released needs to be large enough to act as a cohesive unit and provide growth and reproductive information which realistically reflects conditions at the release site.

A group of five bilbies (two males and three females) per release site has been found to be a manageable size for a sample unit and provide suitable data. One person may experience difficulties in effectively monitoring more than 2 x 5 animals and their progeny at a time. Individuals will need to be supplemented to maintain this complement. Colony size may be increased to lessen demographic extinction risk if the program proves viable. The distance between replicates may also be designed to allow males from adjacent pens to eventually overlap with separate groups of females.

2.1.4 Securing animals for release

Captive breeding colonies have been established at the AZRI in Alice Springs (NT) and at the Western Plains Zoo in Dubbo (NSW). Both these facilities can produce stock suitable for release. Ideally, the captive-bred animals used in a reintroduction program need to:

- have a known lineage;
- represent the remnant genetic variability within the species; and,
- be in healthy condition and free from diseases which might be carried to the wild.

These qualities are required to ensure the animals are appropriate candidates for release and likely to have similar rates of survival and fecundity once released. Variability within and between sample unit composition needs to be low if the effect of the environment on population survival is to be monitored accurately.

Mature breeding adults are an advantage to release because:

- their fertility is proven;
- no maturation time is required before production of *in situ* bred young; and,
- radio-collaring procedures are less risky (see **Section 2.71**).

It has been argued that the use of wild caught animals is far more appropriate in release operations than captive-bred individuals (Chivers 1991). However, there are some significant advantages with the use of captive-bred stock:

- animals are accessible and generally readily available; and,
- the condition, age and composition of the animals released can be carefully controlled.

Whether captive-bred bilbies have less ability to survive than translocated stock is unresolved and needs to be tested at some stage (see **Section 4.4, Volume II**). For the moment it is advised that captive-bred animals be used for released. It has been demonstrated they can adapt to free-range conditions admirably.

2.2 Site selection and preparation

The implementation of a bilby reintroduction program will require approval from the relevant State or Territory government conservation authority and the Bilby Recovery

Team. A thorough assessment of a proposed release site must be conducted to investigate the condition of the habitat and determine the potential for management to alter these conditions. First, it must be recognised that a large area of land is required and activities such as predator, rabbit and stock control and fire management may have to be implemented. Second, the consequences and objectives of the proposed program need to be discussed thoroughly with local conservation officers, animal pest and weed control authorities, bush fire control authorities and neighbours.

2.2.1 Size of area and a functional population

Successful re-establishment of a species requires enough land with suitable habitat to sustain a viable population. As discussed in **Volume 2**, it is not known what constitutes a viable population for most mammal species. A "ball park" figure of 500 breeding individuals has been calculated from genetic research (Franklin 1980) but this number is unlikely to be of sufficient size to act as a viable population for all species (Soule 1987). However, the figure of 500 breeding animals is probably an adequate number for a subpopulation where a species is represented by individuals in several spatially independent subpopulations. Therefore, if a species' re-establishment is contemplated for a particular location, it should be of sufficient size and productivity to accommodate at least in the order of 500 animals.

Based on studies of 14 wild bilby populations, individuals were found at a maximum density of 16.7 animals km^{-2} to a minimum of 1.9 animals km^{-2} (Southgate 1990c). These values represent the ecological density of each sub-population and were calculated from the area actually occupied by a bilby population; the estimates did not incorporate unoccupied habitat. Bilby density was correlated with food quality and its availability.

The density of animals at the WNP release site ranged from 27 animals km^{-2} (composed of recently released animals and their progeny relying predominantly on supplied food) to 3.5 animals km^{-2} (when the population was well dispersed two years after release with over half having to rely on native food).

Using these densities, it is reasonable to expect that 500 animals could be accommodated in 18.5 - 30 km^2 where favourable food was in (unrealistically) continual abundance. At the other end of the spectrum, an area in the order of 140 - 260 km^2 would be required to accommodate the same sized population where favourable food was scarce.

If re-establishment of the species is not the priority, at least 25 km^2 of suitable habitat should be available in which to conduct the reintroduction program because of the high mobility of bilby males and the need to obtain environmental information from a broad environmental base (e.g. predator pressure and food limitations).

2.2.2 Habitat pre-requisites

There is no point releasing animals into a situation where the rapid decline of a population is going to be a highly likely outcome. However, this may be legitimate if it is done under controlled conditions with clear objectives to distinguish among limiting processes. In normal circumstances, the presence of resources or, conversely, known limiting conditions will form the bench-mark to assess whether a location is suitable for occupation. The measurement of environmental characteristics prior to the release of animals plays a crucial part in the overall viability assessment of a reintroduction program. A proposed release site will need to be described and estimates made of key habitat parameters such as predator density for comparison with known acceptable conditions (**Table 2.1**).

Table 2.1 The prerequisites and desirable habitat conditions for a bilby reintroduction site

Attribute	Condition		
Soil	Sands - clay textured soils suitable Coarse fragment abundance (silcrete or laterite) presence acceptable		
Vegetation cover	Less than 35% ground cover required Post fire early successional stages desirable		
Food	*Highly desirable*: native annual grasses - *Dactyloctenium radulans* and *Yakirra australiense* native bulbs - *Cyperus bulbosus* *Acacia* spp. which support root-dwelling larvae (witchetty grubs) Nasute termites		
Predators	*Highly desirable*	*Possibly acceptable*	*Unacceptable*
	< 0.15 cats km $^{-2}$	0.16-0.24 cats km $^{-2}$	> 0.25 cats km^{-2}
	< 0.15 foxes km $^{-2}$	0.16-0.25 foxes km^{-2}	> 0.25 foxes km^{-2}
	< 0.11 dingoes km $^{-2}$	0.12-0.16 dingoes km^{-2}	> 0.16 dingoes km^{-2}
Competitors	*Highly desirable*	*Possibly acceptable*	*Unacceptable*
	no rabbits, no cattle	< low stock, no rabbits low rabbits, no stock	< sheep; cattle & rabbits

2.2.2.1 Soil and landform

The soils present at a site must be suitable for burrow construction. Bilbies can dig burrows in soil with texture ranging from medium clay (if friable) to coarse sand. Known suitable soil types include siliceous and earthy sands, loams, brown calcareous cracking clays, non-calcareous massive earths and duplex soils (Southgate 1990c). The soils can contain a substantial amount of coarse fragment matter such as laterite or silcrete but it may take longer to establish burrows in these soils. Burrows can be constructed in a variety of locations but are rarely found in soils prone to waterlogging, e.g. swales.

Bilby populations in the wild appear to persist best in landscapes where laterite or silcrete residual outcropping occurs in combination with drainage lines. There are a number of reasons why this type of habitat may be favoured (see **Volume II**). If possible release sites should be chosen exhibiting these landform characteristics.

2.2.2.2 Cover

Extant bilby populations occur in open habitats probably because individuals find it difficult to forage and move around in dense ground cover. The vegetative ground cover should not exceed 35% (Southgate 1990c). A minimum amount of cover is not required and bilbies will happily occupy "moon-scape" environments if suitable food resources are present. Cover of vegetation will need to be monitored with methods described in **Section 2.7.7**.

2.2.2.3 Food resources

The presence of foods known to be important to the bilby such as *Cyperus bulbosus, Dactyloctenium radulans* and *Yakirra australiense* and certain shrub species containing witchetty grubs will be indicative of potentially favourable habitat (see **Box 5, Volume III**). Other important foods probably occur in the bilby's former range; these may become apparent by monitoring the diet of released animals. Plant composition may be monitored with the same methods used to measure cover (see **Section 2.7.7**).

2.2.2.4 Predators

From the work at WNP and SGNP, foxes and feral cats at densities in the order of 0.15 animals km^{-2} and dingoes at 0.11 animals km^{-2} in combination associated with an expanding population. Densities in the order of 0.25 animals km^{-2} for cats and foxes and 0.16 animals km^{-2} for dingoes in combination associated with a declining population. Densities exceeding these values may be tolerated where one or more of the predator species is absent or habitat productivity is higher. Predation by pythons was significant near rocky country in SGNP. Methods to monitor predator activity and density are outlined in **Section 2.7.3**

2.2.3 Land use and the potential for management

Areas of land with kangaroos, horses, cattle and rabbits at low densitiy may be suitable for reintroduction of the bilby. However, there are no bilby colonies left in country used for predominantly sheep or where high cattle stocking rates exist. The great challenge is to establish whether it is possible to re-establish the bilby into landscapes altered substantially by the effects of stock and rabbits and to determine compatible land use and management practices.

There is little logic in releasing animals into habitats which require a high degree of management or where management is unlikely to be maintained in the long-term. However, situations such as these may prove useful to learn more about the species under different field conditions in the short-term. The abundance of stock and rabbits may be measured using transects to monitor predator activity (see **Section 2.7.3**).

2.2.4 Selection of a release site

Careful consideration must be given to siting the release pens. They must be located to enable easy access for monitoring and management. There will be less incentive to monitor the population adequately if the release site is too far away or too difficult to reach. It is possible to locate them quite close (one to two kilometres) to human habitation for example, although predator control measures may be more risky to implement and domestic pets and livestock may be a problem. Pen-sites require a well drained, friable soil such as on raised land or near a sand hill.

Phase 2 The transfer of constrained animals to a free-range existence

2.3 Condition assessment, trapping and transfer of animals

In this section the methods of transporting, handling, and assessing the condition of the release stock are discussed. These procedures involve the trapping of animals so trapping techniques are included. A set of operational rules appropriate for Phase 2 is presented in **Fig 2.3**.

2.3.1 Monitoring an animal's condition

Each time an indivual is caught it is important to monitor its condition. Stress and injury during transportation or acclimatisation may cause a rapid deterioration in the condition of an individual. In the event an animal dies, an accurate account of the conditions associated with its death, in addition to an autopsy, is necessary.

The condition of each individual should be thoroughly checked before release; each animal needs to be in good physical condition before being exposed to a free-range existence. At each step the condition of individuals destined for release should be assessed otherwise the link between habitat condition and population survival and fecundity will be distorted.

Objectives:

- To record an animal's physical and reproductive condition in the transition from the captive colony to the pen enclosure, in the pen enclosure and, after release; and,
- to ensure a radio-tracking collar (if used) is fitting and working satisfactorily and not stressing the individual (see **Section 2.7.1.1**).

Procedures:

- A proforma is provided in **Appendix 1** indicating the type of information which should be recorded each time an individual is captured.
- Weigh each individual and establish its identity if marked.
- Assess the condition of the animal by running your hand along its back. Condition can be roughly separated into three categories:
  - poor condition: hip and vertebrae can easily be felt.
  - good condition: slight boniness.
  - very good condition: rounded form of back, no bones felt.

PHASE 2: THE TRANSFER OF CONSTRAINED ANIMALS TO A FREE-RANGE EXISTANCE

QUESTION 1: **HAVE THE ANIMALS BEEN THOROUGHLY EXAMINED AND ARRIVED AT THE REINTRODUCTION SITE IN GOOD CONDITION?** (see Section 2.3)

YES Release animals into a temporary yard; Go to Question 2.
NO **Do not release animals**, must account for the condition of each animal before they are released into a temporary yard.

QUESTION 2: **HAVE THE ANIMALS SETTLED INTO THE ACCLIMATISATION PEN AND MAINTAINED THEIR CONDITION?** (see section 2.4)

YES Release animals from a pen after at least a four week acclimatisation period; Go to Question 3.
NO **Do not release animals**, animals not be released until the cause for their deterioration in condition has been determined and remedied.

QUESTION 3: **DO THE ANIMALS REMAIN WITHIN THE VICINITY OF THE PENS SHORTLY AFTER RELEASE?** (see section 2.5)

YES Continue monitoring movement and survival of animals; Start Phase 3 of program. (See Fig. 2.4 and 2.5 for detail).
NO **Recapture over-dispersed animals and return to their respective pens.** Animals must remain a cohesive unit otherwise individuals will not contribute to breeding. Go to Question 2.

Fig. 2.3 Operational rules for Phase 2 of a bilby reintroduction program.

- Examine the animal for wounds and note the extent of hair loss, scaly skin or balding.
- If an animal is wearing a radio collar, check whether the collar is fitted correctly. If the collar has broken the skin or is causing ulcers it must be removed immediately. Check the aerial, collar and transmitter for wear and development of abrasive points.
- Check whether females have everted nipples (10-20 mm length and sign that the female is lactating) or inverted nipples (3-10mm length).
- If the females have pouch young then estimate their age using the length of head, emergence of vibrissae, pigmentation and pelage development in accordance with the key developed by McCracken (1983) in **Appendix 2a**.
- Record head and foot measurements and track size of the captured animal if required (**Appendix 1**).
- Collect the scats from a known animal; check the trap and the holding bag.
- Tattoo or ear-tag unmarked (new) individuals.

2.3.2 Necropsy procedures and assessing the cause of death

Objectives:

- Determine the proximate causes of death;
- collect and store an animal for necropsy; and,
- ascertain the cause of death of an animal by autopsy and pathology.

Procedures

- When a dead animal is discovered record the time, date, location and collector. A proforma listing the information that should be recorded is presented in **Appendix 3**.
- Describe the condition in which the animal was found and how long it had been in that condition.
- Describe the weather at the time of discovery and what it had been like recently.
- Include a description of possible cause of death and a photograph of the site.
- Collect as much of the animal as possible; sub-sample or collect blood and organs and store appropriately to prevent decay.

2.3.3 Trapping

Objectives:

- To live-trap released individuals and the progeny of released individuals (referred to as *in situ* bred individuals) for condition assessment, possible recollaring and relocation.

2.3.3.1 Cage trapping

- Tomahawk, large Elliott or standard swing-door traps baited with seed may be used to catch bilbies (see **Appendix 4** for specifications and trap manufacturers).
- The most successful trapping sites tend to be near feed hoppers or adjacent to the pen fence. Traps need to be easily located (otherwise they can be overlooked, especially at night).
- Traps need to be covered with a sack. This aids trap stability and prevents animals from digging under the traps to obtain the bait; during winter the cover helps keep in warmth and during summer provides shade. The dark environment also reduces animal stress.
- Traps should be cleared once during the night to:
  - enable resetting of traps sprung accidently;
  - clear occupied traps; and,
  - relocate captured animals to a more favourable and secure point.
- All traps must be cleared as soon as possible after sunrise to avoid animals becoming stressed by heat or attack by ants.
- Do not shake or drag the animals out of traps; instead, place a hessian bag over the trap opening and gently encourage the animal to enter a bag.

2.3.3.2 Yard trapping

- This procedure uses cage traps in combination with a fence to concentrate trapping effort around a burrow known or suspected to contain an animal (**Appendix 5 and Fig. A5.1**). The trap is constructed by surrounding the burrow with wire mesh sections; cage traps are placed inside the yard and/or in holes cut in the fence feeding out of the yard trap. The cage traps may be covered and supplied with food but the back end should be left exposed giving the impression of an exit.
- Check for the presence of alternative burrow exits.
- Animals will occasionally remain down a yard-trapped burrow on the first night; maintain the trap for no longer than two nights to prevent the possibility of starvation.

2.3.3.3 Tent trap

- A modified version of the yard trap was developed for use on burrows with relatively small entrances, such as those constructed by juveniles. This trap has a fixed base onto which the footing is attached.
- A separate tent section, enclosing the burrow, is then secured to this base once the footing has been covered with soil.
- An Elliott or Tomahawk trap is placed in a hole cut in the mesh feeding out of the tent trap as described above.
- Check traps and relocate trapped animals as described above.

2.3.4 Transporting, holding and handling

Objectives:

- To ensure handling and transportation of animals causes no physical harm and minimal stress to the individuals.

Procedures:

- When moving animals, place individuals in separate hessian bags, securely tie the bag and carry in a plastic washing basket or similar. Three animals in bags may be carried safely in one washing basket.
- Store animals in a cool place never above 35^{0}C, out of direct sunlight if hot, and out of the reach of any ants. For short periods, the hessian bags may be moistened to promote evaporative cooling.
- If holding animals overnight, release an individual into a covered cage trap and provide a quantity of seed and muesli for food. If pressed for space, two females or one male and one female may be placed in one trap. It is preferable and less stressful to have one animal per trap.
- It is preferable to handle and check animals during daylight hours. At night individuals are far more active and harder to handle.
- Secure an animal by firmly holding the base of the tail. Keep the individual enclosed in the hessian sack as much as possible while it is being handled and keep it supported on a table or on your lap.
- Avoid dragging an animal out of a bag or letting it drop to the bottom when it is being replaced.

2.4 Establishing animals in temporary enclosures

The animals transferred to a release site need to be acclimatised to their new environment before release. In general, individuals from these colonies will have had very little experience of digging a burrow, obtaining native foods or avoiding predators. They must become accustomed to being trapped and develop a keen affinity with the penned area, the placement of burrows and location of supplied food and water.

The pen design suggested is suitable to contain animals for several weeks and is not intended to be predator proof. A more permanent enclosure would not be as easily constructed or transported; in most situations, predator density in the release area should be at acceptable levels prior to release (**see Section 2.2.2.4**).

2.4.1 Pen design and acclimatisation of released individuals

Objectives:

Construction of a simple and sturdy pen, easily manufactured and transported, which maintains animals securely during the acclimatisation period.

2.4.1.1 Pen size

- A 50 x 50 m pen is a suitable size for a combination of two adult males and three females enabling the development of foraging and burrowing skills.
- Females are tolerant of males and one another. However, more than two males in the presence of females in the limited pen size may prove stressful.
- A minimum of two pens will need to be constructed (see **Section 2.3.1.2**).

2.4.1.2 Pen spacing

- Released individuals will generaly establish their home range around the release pen. Separation of the pens will spread the home ranges of the released animals apart.
- While food is provided, the home range of released females will generaly centre around their pen and most will use burrows constructed within 500 m from a locality.
- Males will range more widely than females; if pens are placed one to two kilometres apart, it is likely that males released from one pen will locate the other, begin using the supplied food facilities and visiting females in nearby burrows.

- Based on movement and dispersal rates (**Box 3, Volume III**), pens need to be spaced aproximately three kilometres apart to act as independent replicates during the early phases of the reintroduction operation.

2.4.1.3 Pen construction

- Electric fencing is not required in the pen construction.
- A design using six rolls of 50 m x 900 mm x 25 mm chicken mesh is suitable to hold released animals and act as a deterrent to predators. Two of the rolls are cut in half and these half sections are ring fastened to form the footing of the four complete rolls (**Appendix 6 and Fig. A6.1**).
- The ground surface needs to be cleared of vegetation in a one metre-wide strip around the perimeter of the fence with the use of a front-end loader or by dragging a heavy object behind a vehicle.
- The 900 mm upright section of mesh can be ring fastened to a single strand of fencing wire threaded through star pickets placed 10 m apart. The corner pickets of the pen may need to be supported to allow straining of fencing wire.
- The wire netting needs to be placed on the pen-side of the star pickets to prevent animals colliding with the star pickets.
- The footing of the fence should face inwards to prevent the bilbies from digging out. It needs to be flush with the ground surface at all points and covered with dirt. Avoid digging holes close to the footing on the internal perimeter of the pen as these may be developed into burrows by the resident bilbies.
- Water (supplied to "pig drinkers") and food hoppers containing small parrot or budgerigar seed mix need to be placed in each pen. The dimensions and design of the food hoppers are provided in **Appendix 6 and Fig. A6.2**.

2.4.2 Introducing the bilbies to the pen

Objectives:

- To ensure the preliminary activity of released animals includes construction of a burrow.

Procedure:

- Before bilbies are allowed access to the 50 x 50 m pen they need to be introduced to a smaller internal pen (3 x 3 m).
- This can be a yard trap design (see **Section 2.1**) and is used to limit the movement of the newly introduced animals and encourage them to construct a burrow before being allowed to investigate the larger pen.

- Removal of several spade-fulls of soil from inside the yard may stimulate burrow construction at that point.
- Two or three animals can be placed in one of these small pens until a burrow has been constructed. Maintain the pen for two nights then it may be dismantled and removed.
- Additional animals can be added to the 50 x 50 m pen without this procedure if suitable burrows already exist.

2.4.3 Management of the animals while in the pen

Objectives:

- Encourage animals to associate the provision of food with a specific point in the enclosure;
- accustom the animals to being trapped; and,
- monitor the acclimatisation and health of animals prior to full release.

Procedure:

- Initially monitor the enclosure each day to:
  - ensure released animals occupy a burrow;
  - check the security of the fence;
  - check for sign of predators; and,
  - check the location of animals (if they have radio collars) to establish which burrows are being used, which animals are sharing burrows, if individuals are moving around and the functioning and strength of radio collars.
- Place feed hoppers in one location in the pen preferably near the watering point.
- Provide food and water within the enclosure during the establishment procedure.
- The animals will gradually develop a set of burrows inside the pen.
- Individuals will share burrows but frequently will occupy a burrow on their own. The degree of burrow sharing in penned animals is discussed in **Box 2, Volume III**.
- During the period when the animals are penned it is important to become familiar with the appearance of bilby burrows, their diggings, scats and tracks as these signs are used to monitor dispersal and habitat use away from the release site.
- Bilby individuals will "patrol" the internal perimeter of the fence. This is not an indication that the animals are ready to be released from a pen.

2.5 Release of animals from temporary enclosures

It is important that the animals remain as a cohesive unit and within a localised area when first allowed to free range from the pen. This makes the recapture, management and monitoring of the animals much easier and allows the animals to gradually develop a knowledge of the resources in the area while in close contact with supplied food and established burrows. In order to survive, released animals will need establish their own home range boundaries and become familiar with the resources in their home range.

2.5.1 Release of animals from a pen

Objectives:

- To assist animals to orientate themselves; and,
- to encourage animals to remain in the vicinity of the release area and maintain social contact.

Procedure:

- Animals can be released from the pen enclosure after a minimum four week acclimatisation period.
- Separate the release of each pen by two weeks to ease the monitoring effort. The first pen will also act as a test run.
- Cut a hole in each side of the pen fence to allow the animals to come and go as they please. It may be necessary to block and/or trap these exits from time to time so make the size of these holes suitable to fit a trap.
- Maintain the availability of food in hoppers within the enclosure. Animals must be encouraged to use the pen as a focal point and providing food is the key. It may also take some individuals several nights to locate the exits and make their way out of the pen.
- The first few days after release are critical. It is important to check on the locality of animals with radio-collars early each day to establish if they leave the pen.
- It is an advantage to check the location of animals more frequently (e.g. once or twice a night) to establish if they remain in transmitter range and the general direction of their movements.
- Some animals may become disoriented and exhausted from their activities and attempt to construct inadequate burrows in inappropriate places.
- Generally, one in five of the animals will head off, moving away from the pen. If these animals can be located and it appears they would not be able to relocate the pen with the trend of their movements they would need to be retrieved by trapping.

- Distances of more than 1000 m in the first few nights are considered excessive for both males and females.
- Once trapped and returned to the pen, the animals tend to settle their activity.
- The rate of burrow sharing will change as animals construct burrows and develop home ranges outside the pen (see **Box 2, Volume III**).

Phase 3 Free-range animals and the recipient environment

2.6 The relationship between a population and its recipient environment

Once the animals have learnt that it is possible to come and go from a release pen as they please, the most crucial part of the reintroduction program can begin. We can now start collecting information about the response of the released animals to the recipient environment. The detail and the type of information obtained will depend upon the program's resources and techniques implemented. A range of procedures to collect information from both the bilby population and the environment are provided. A set of principles are outlined to direct the implementation and organisation of these techniques.

2.6.1 Population vigour and habitat "favourableness"

The health and vigour of individuals and the growth of the population will be largely influenced by and reflect the conditions at a release site. The relationship between a species and its environment can be represented by this simple equation:

$$r \propto F$$

where r = the population growth rate
F = the habitat favourableness

A population's response to habitat favourablity may be readily measured. Accurate estimates of population abundance or, alternatively, age-specific fecundity and survival rates can be used to determine population growth. Other population parameters such as the rate of growth of individuals, litter size and frequency, home range size, dispersal rates and diet may be used to indicate population vigour and its potential to grow.

The characterisits of a species' environment may also be measured and in doing so it is important to concentrate on characteristics which have most affect on the population. It is useful to divide the environment into sections as shown in **Fig. 2.3**:

- "below" (eg. food resources etc);
- "above" (eg. predators); and,
- to the "side" (eg. competitors).

The growth of a bilby population will be dependent largely upon "top down" pressure from predators and "bottom up" constraints resulting from food limitations. Altered predator pressure or food availability will result in altered population performance. Competitors rarely affect the dynamics of a population directly; instead they influence the factors "below" (by use of common food resources) or "above" (by acting as alternative prey for predators). Consequently, the influence of these organisms may be safely examined via food resources and predators.

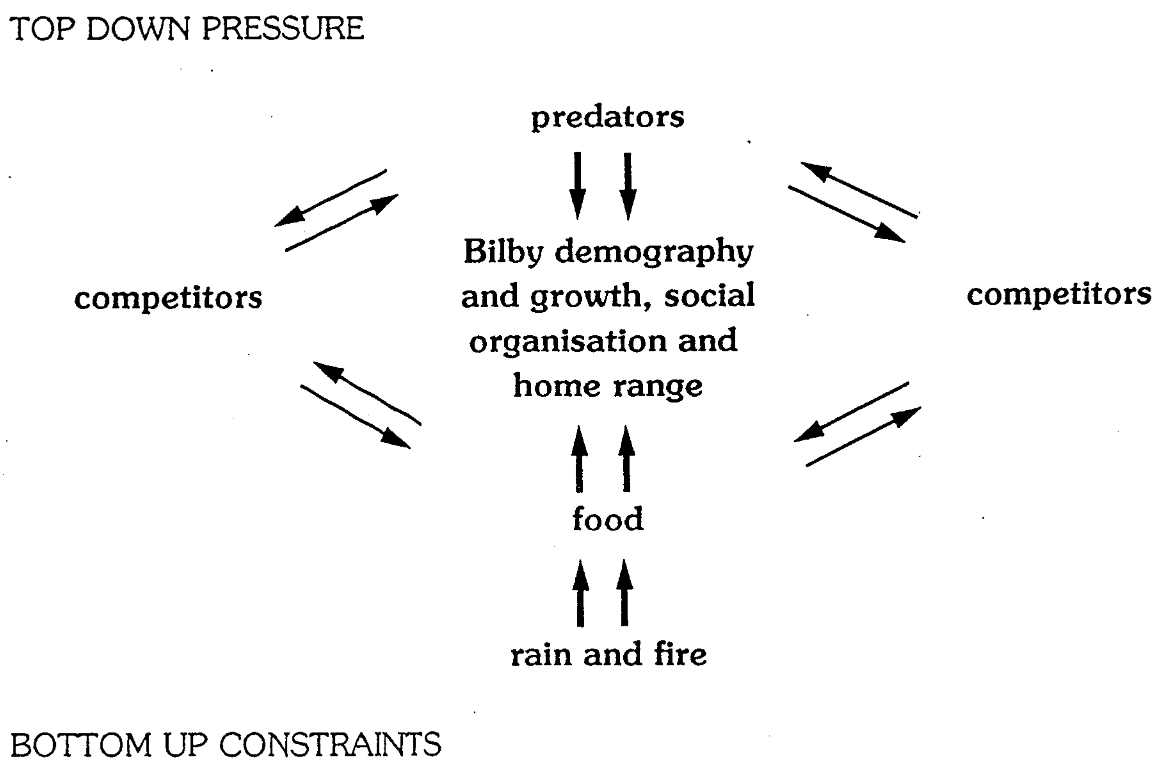

Fig. 2.3 Summary of the linkages between the bilby population and components of the environment.

2.6.2 Monitoring principles

A number of principles have been developed to help direct monitoring effort and ensure resources are not wasted:

1. Reintroduction as a research tool

Reintroduction must remain a research tool until we can confidently predict the growth of a reintroduced population by simply monitoring specific features in the environment. It is hoped that this document will encourage a rigorous scientific approach to the reintroduction of the bilby.

2. Compatable techniques and comparable information

Information produced from a reintroduction program needs to be comparable to that obtained from another time or location. The procedures presented in this document will hopefully facilitate the implementation of compatable techniques within and between reintroduction programs.

3. Monitoring protocol

The primary aim of monitoring is to increase our understanding of how the population responds to environmental conditions. A set of decision rules to guide the monitoring of population dynamics is provided in **Fig. 2.4**. Decision rules to guide the implementation of environmental monitoring are provided in **Fig. 2.5**.

4. Monitoring duration and scale

A period of 24 months is the minimum duration time over which a program should be monitored. The acid test is to determine if mature offspring can be produced by the first generation of *in situ* bred animals (i.e. the young of the released animals). The time taken for this to occur is effectively a generation time which is approximately 24 months for the bilby. A study area of least 25 km^2 is needed to accomodate the reintroduced population during the minimum program duration. **Fig. 2.6** illustrates schematically a possible arrangement of sampling strategies at a release site.

5. Monitoring intensity

Unless specified, monitoring should be conducted systematically on three monthly basis for the first 24 months. The monitoring frequency corresponds with the natal period for young (i.e. pouch life and and time as young-at-foot before independence). After 24 months the monitoring should be in response to changes in the bilby population and environment at the reintroduction site.

6. Monitoring procedures

Monitoring the bilby population and the environment may be conducted intensively (individual animals) or extensively (the whole population) and directly (e.g. radio tracking) or indirectly (e.g. tracking transects or burrow checks). Intensive and direct monitoring procedures should be implemented and maintained where possible because they are most desirable in terms of the information produced. However, these procedures are more costly in terms of effort and resources and often indirect procedures are more practical.

7. Monitoring design

A number of different monitoring procedures may be used to provide similar information on population trend or environmental condition (see **Table 2.2**). Where possible, two or more monitoring techniques should be implemented simultaneously to provide backup or confirmatory information about a particular topic.

8. Infrastucture minimisation

The infrastructure costs and the extent of permanent fixtures associated with a reintroduction program should be minimised where possible. If large amounts of capital have been invested and infrastucture developed it becomes difficult to terminate or rationalise an inappropriate program.

9. Program termination

The operation should be terminated if the conditions at a site become unacceptable and the rapid decline of individuals in the population is evident. Animals should be recaptured and relocated to another program or placed in captivity.

QUESTION 1: **IS THE POPULATION SIZE INCREASING?**

YES Review monitoring procedures with a view to reducing effort.

NO Determine why the population is declining. Go to Question 2.

QUESTION 2: **ARE RELEASED FEMALES CONCEIVING?**

YES Go to Question 3.

NO Could be the result of a number of factors. Look for evidence of mating irregularity or poor condition in released females. Go to Question 7.

QUESTION 3: **ARE YOUNG OF RELEASED FEMALES SURVIVING POUCH LIFE?**

YES Go to Question 4.

NO Look for evidence of poor condition in females. Poor nutrition of released individuals likely to be reducing pouch young survival; examine diet and determine if still using food hoppers.

QUESTION 4: **ARE *IN SITU* BRED JUVENILES REACHING MATURITY?**

YES Go to Question 5.

NO Look for evidence of difference in mortality between smaller sized young and adults. Predator pressure or inability to obtain adequate food may be limiting juvenile survival. Capture and radio-track both released and *in situ* bred juveniles to determine mortality factors.

QUESTION 5: **ARE *IN SITU* BRED ADULTS (RELIANT ON NATIVE FOOD) ABLE TO REPRODUCE EQUALLY AS WELL AS RELEASED ANIMALS (WITH ACCESS TO SUPPLIED FOOD)?**

YES Predation likely to be having a major impact on the population. Determine predator abundance and predator diet. Capture existing animals and discuss future of reintoduction program with Bilby Recovery Team.

NO Poor nutrition of *in situ* bred animals may be resulting in low fecundity and limiting population growth. Examine diet of animals and conduct survey of access and availability of food.

QUESTION 7: **DO MATURE FEMALES AND MALES EXIST IN THE POPULATION? ARE THE MALE AND FEMALE YOUNG BEING PRODUCED IN NEAR EQUAL PROPORTION?**

YES Go to Question 8.

NO Release either males or females to increase breeding population and reduce disparity of sexes.

QUESTION 8: **IS MATING OCCURRING? ARE MALES AND FEMALES SHARING BURROWS? IS THE POPULATION REMAINING AS A SOCIAL UNIT?**

YES Go to Question 9.

NO Recapture animals and hold in pens, examine if mating and conception occurs under these conditions. Contact Bilby Recovery Team.

Fig. 2.4 Monitoring population trend

QUESTION 1: **HAS PREDATOR ACTIVITY BEEN MONITORED IN THE LAST 3 MONTHS?**

YES If predator density falls within acceptable levels, go to Question 2. If **not** as above, then assess survival and fecundity of the bilby population and increase the frequency of monitoring predator activity. Go to Question 4.

NO Record predator tracks and predator scats along predator transects. Go to Question 1, Yes.

QUESTION 2: **HAVE VEGETATION TRANSECTS BEEN MONITORED IN THE LAST 3 MONTHS?**

YES If vegetation ground cover is less than 35% and composition is stable, go to Question 3. If **not** as above, then check survival and fecundity of the bilby population; examine vegetation cover more extensively and review fire management options. Go to Question 3.

NO Collect vegetation cover and composition data along vegetation transects. Go to Question 2, Yes.

QUESTION 3: **HAS THE DIET OF THE BILBIES BEEN ASSESSED?**

YES If the diet composition is similar to previous diet sample, go to Question 6. If **not** similar, check the survival and fecundity of population. Identify the items in the diet which have altered, and those items which are being provided by the existing vegetation. Investigate invertebrate food availability. Go to Question 4.

NO Collect bilby scat material and conduct diet analysis. Go to Question 3, Yes.

QUESTION 4: **HAS SMALL MAMMAL ANIMAL TRAPPING BEEN CONDUCTED?**

YES Determine the relationship between diet of the bilby and plant and invertebrate resources. Go to Question 5.

NO Conduct small mammal and invertebrate trapping and monitor invertebrate transects. Go to Question 4, Yes.

QUESTION 5: **HAS THE DIET OF PREDATORS BEEN ASSESSED?**

YES Determine the relationship between small mammal and invertebrate availability and predator diet Go to Question 6.

NO Collect predator scats from predator transects and determine their composition. Go to Question 5, Yes.

QUESTION 6: **HAVE THE EFFECTS OF DISTURBANCE (FIRE), RAINFALL AND TEMPERATURE ON FOOD AVAILABILITY BEEN DETERMINED?**

YES Determine the relationship between disturbance, rainfall, temperature, food availability and bilby diet. Go to Question 7.

NO Establish fire plots or exclusion plots. Monitor the response of vegetation to this treatment compared to control areas and monitor the response of vegetation to rainfall and temperature. Go to Question 6, Yes.

QUESTION 8: **HAVE PROCEDURES TO GAUGE COMMUNITY COMPOSITION AND RICHNESS BEEN IMPLEMENTED?**

YES Determine if there are components of the species assemblage which can be effectively used to indicate habitat favourability for the bilby. Time for a holiday as well.

NO Determine the community richness and composition indices and compare with data from areas within the current and former distribution of the bilby. Go to Question 7, Yes.

Fig. 2.5 Summary of procedures for monitoring habitat favourability

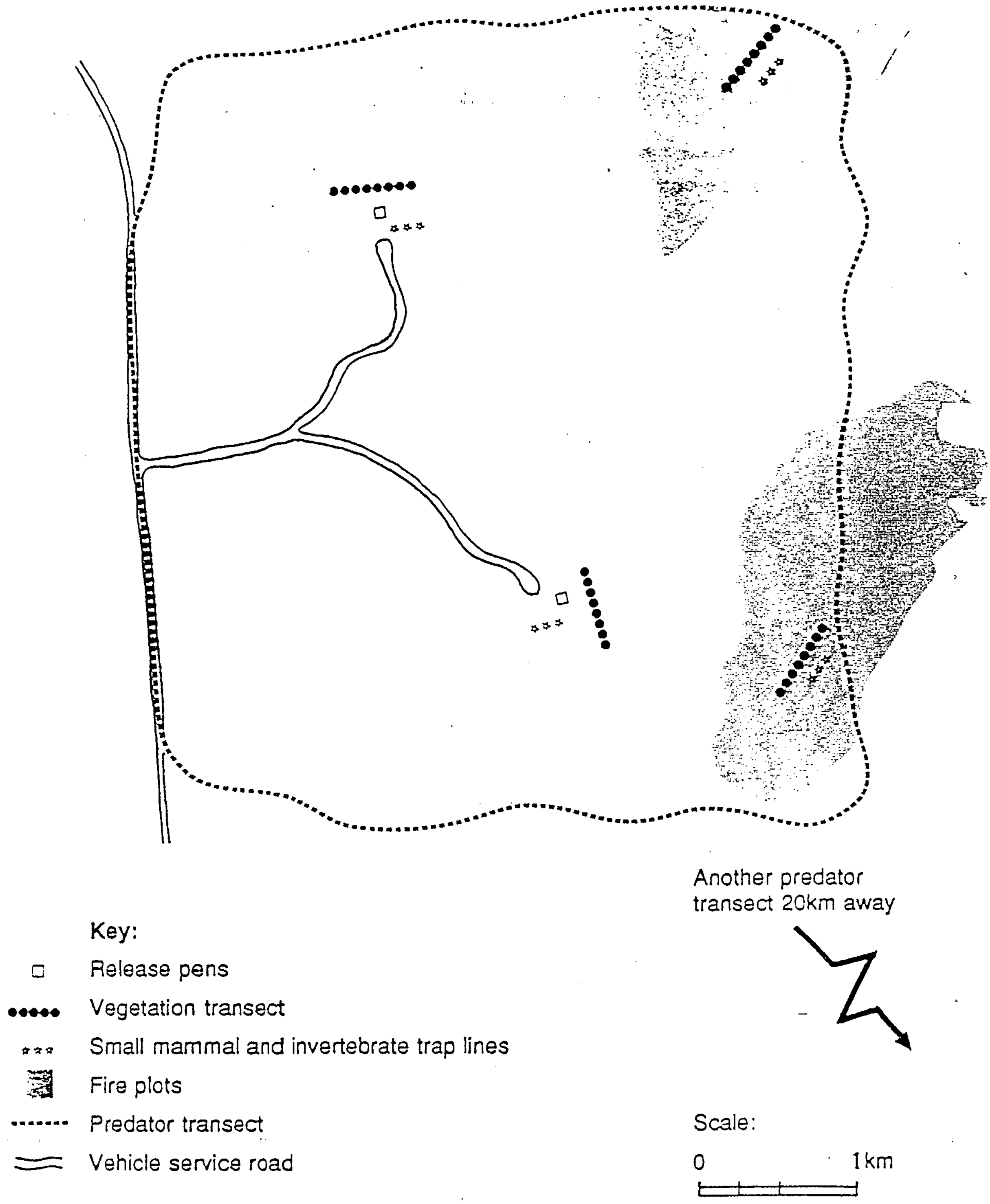

Fig. 2.6 Schematic and idealised diagram of environmental sampling strategies at a bilby reintroduction site.

Table 2.2 Summary of the linkages between the sampling procedures outlined and key areas of interest

Sampling procedures	*Key interest areas* Bilby distribution & dispersal	Bilby survival & fecundity	Bilby diet	Food accessibility & availability	Predator abundance & diet	Community richness
Radio tracking	x	x	o	-	-	-
Burrow checks	x	x	o	o	o	-
Tracking transects	x	x	-	o	x	-
Spot lighting	o	o	-	-	x	o
Scat collections	o	o	x	o	x	-
Diet analysis	o	o	x	o	-	o
Vegetation transects	-	o	o	x	-	x
Rainfall records	o	o	o	o	o	o
Soil & landform mapping	-	o	-	x	o	x
Fire plots	o	o	o	x	-	x
Small vertebrate & invertebrate sampling	-	-	o	o	x	x
Bird transects	-	-	-	o	o	x

Key:

x primary link, i.e. a procedure used directly to obtain information on one of the key area of interest

0 secondary link, i.e. information for key interest areas obtained indirectly by these procedures

\- no link

2.7 Monitoring techniques

2.7.1 Radio tracking

Radio tracking provides a technique to directly determine the survival and specific location of known individuals. However, the collar mounted transmitters and radio receiving equipment are expensive and substantial time is required to replace and maintain functional collars on animals. Monitoring programs are frequently hampered by unpredictable transmitter failure, limited collar strength, collar weight, transmission range and battery life. These problems make the technique suitable mainly for adult animals but particularly risky for juveniles. Nevertheless, the technique is widely used and equipment from several manufacturers has been tested on bilby individuals with satisfactory success. Equipment, field techniques and data analysis are discussed in Kenward (1987), White and Garrott (1990) and Amlaner and MacDonald (1980).

Objectives:

- Determine the length of time individuals survive;
- locate animals in the field for recapture;
- determine the movements of and habitat used by radio-collared individuals; and,
- determine the degree of interaction between individuals.

Procedures:

- The equipment used in radio tracking and the general background to the technique are presented in **Appendix 6**.
- Radio-tracking may be used to locate individuals in burrows during the day or to monitor movements of animals foraging at night.
- Continued movement of an individual between burrows and changes in the pitch of a radio signal caused by changes in collar (aerial) orientation indicates that an individual down a burrow is still alive; a constant signal from the same burrow on several consecutive days suggests the animal may be dead.
- Movement and broad habitat use by individuals may be adequately inferred by noting burrow occupation.
- Daily location of collared animals should be conducted in the early stages of a release program. Sampling effort may be reduced when the movement of animals can be reasonably predicted.
- The movements of collared individuals may often place them beyond the transmission range of the equipment even with the use of receiving aerials placed on radio-tracking towers. With transmitters working correctly and hand held receiving aerials, a range of 800 m can be attained for animals located in a burrow. There is often variability in the transmitter power; 1500 m range has

been achieved for some and less than 400 m for others.

- A proactive approach should be adopted to locate collared individuals. Tracking needs to be conducted from a number of tracking points situated approximately one kilometre apart throughout the release area. These points should be located at high points in the landscape and follow the spread of bilby activity.
- If a certain individual is not located, previously used burrows should be revisited and radio tracking conducted over a more extensive area. Tracking at night should be tried; as tracking range generally increases while the animals are above ground.
- Regular tracking enhances the potential to locate collared animals:
  - Familiarity with the behaviour of radio-tracked individuals is increased with regular tracking; and,
  - faults and deterioration in radio tracking equipment can be determined before contact with animals is lost completely (i.e. a change in signal pulse width and strength can indicate the battery is about to die).
- The data collected should include:
  - the entire tracking area and tracking effort;
  - the position of animals which were located; and,
  - whether individuals were temporarily missing (having moved outside the search area), had a known malfunctioning collar or were unable to occupy a burrow of their own accord i.e. temporarily out of the field operation (trapped out and held).
- Negative information (e.g. an animal is missing) is as important as positive information (e.g. an animal has been located).
- A protocol and proforma to collect information while radio tracking are provided in **Appendix 7**. Compiling data in the suggested format eases the formulation of the survival parameters outlined in **Volume II**.

2.7.2 Burrow location and activity assessment

Monitoring bilby burrow activity provides an indirect means of determining the size (and survival) of the population and their distribution. The size of animals responsible for the observed activity can be determined with some degree of accuracy by recording track size and scat size (**Appendix 1**). Traverses during regular burrow surveys may also be used to systematically collect bilby scats, predator scats and note predator activity.

To be successful, the technique requires comprehensive mapping of burrows, regular assessment of activity and searching for new burrow localities. Burrow checking is a time consuming procedure to be accomplished on foot; several animals can readily occupy a very large area (> 10 km^2). Two hundred burrows within this area can take two days to check. The technique has the disadvantage that known individuals cannot be confidently located.

Objectives:

- Determine the extent of burrow activity and infer the distribution and abundance of the bilby population from the status of the burrows located.

Procedures:

- Burrows can be located by walking through an area occupied by the bilby. In areas where bilby activity is commmon, burrows are generally spaced between 50 and 100 m apart.
- Each burrow needs to be individually numbered with a strong metal tag and flagged with flagging tape; determine the burrow's coordinates or locate its position on a map; provide a reference for it in relation to a permanent point or several other nearby burrows.
- These burrows may then be resurveyed at a later date to assess activity. The activity can be conveniently separated into three categories:

- burrow open, active:	clear burrow entrance with sign of recent use (e.g. tracks nearby, freshly dragged soil etc.).
- burrow open, not active:	burrow entrance may contain spider webs or leaf litter indicating no recent use.
- burrow collapsed:	the burrow would not provide a refuge for the bilby without substantial digging and refurbishment.

- The procedure of mapping burrows, plus noting the burrow activity, the presence of nearby tracks and feeding activity on a regular basis, will indicate where bilbies are centring their activity.
- Monitoring by this means will indicate whether the population is expanding or contracting on a broad scale.
- The format for data must include the number of burrows surveyed, the extent of area surveyed and the proportion of burrows in each activity category. A proforma for these data is presented in **Appendix 8**.

2.7.3 Tracking transects

Under good tracking conditions, several species of mammal and a few birds can be identified by their tracks (Morrison 1981; Triggs 1984). These include the major predators of the bilby and the introduced competitors such as rabbits and stock. The procedure outlined records the tracks of the bilby and other animals on a prepared sandy surface. Transect location and servicing can be designed to cover the management and release area comprehensively (Van Dyke and Brocke 1986). Use of an ATV (All Terrain Vehicle i.e. a trike or quad) permits large areas to be surveyed rapidly with little degradation of the environment. Existing tracks may be suitable for use as transects.

This technique provides an indirect measure of the distribution and abundance of the bilby and other species. There are advantages to tracking transects:

- both presence and indices of species density can be determined by examining the tracks occurring on transects;
- animals at low density or with a shy or secretive nature will leave a record of their presence and sign of animals can be left to accumulate before re-sampling;
- the transects also provide an ideal way to standardise the collection effort for scats from predators and/or competitors; and,
- the transects provide increased access for radio tracking, spot-lighting and bait laying.
- one person on a quad or trike can record the sign of animals while covering the equivalent sample area in the same time;

The use of a tracking transect has limitations because:

- the scores do not equate directly with species abundance;
- factors affecting the activity of a species will be reflected in the score values;
- known animals may not be identified specifically;
- animals may move beyond the range of the transect without detection;
- the construction of these transects may not be appropriate for some release localities;
- wind, rain and disturbance from vehicles or animals can obliterate tracks occurring on the tracking surface;
- the technique works most effectively for species occurring at low density
- skilful interpretation of tracks is required;
- the length of transect needs to be appropriate for the animals being studied; and,
- the tracks may facilitate the movement of predators into an area.

Objectives:

- Determine the track activity of the bilby and its predators and competitors and infer their distribution and abundance from these data.

Procedures:

- Sandy or loamy soil free of rocks provide the best surface for a tracking transect.

- Existing tracks can be used for a transect; alternatively, vegetation can be cleared from a strip with the use of heavy equipment.
- The tracking surface of the transect can then be maintained and prepared by dragging a heavy brush or chain spread by a star-picket behind an ATV. A tracking strip of 1.2 m is an adequate width for a transect.
- Once a clean tracking surface has been prepared, tracks of animals travelling along or crossing the track can be counted.
- Re-sampling conducted on consecutive days provides a sample period of approximately 24 hours per transect.
- For practical reasons, the transects are best designed as a circuit placing the operator no further than 5 km from alternative transport or assistance should the tracking vehicle break down.
- Each transect needs to be divided into cells to allow quantification of the tracks recorded. A cell length of 500 m has proved suitable to accurately measure track intensity. In general, few species, except dingoes, camels and horses, will travel along a transect for more than several hundred metres.
- Tracking can be accomplished satisfactorily while travelling at a rate of 10 $kmhr^{-1}$.
- A species' track within the 1.2 x 500 m cell is scored whether an individual bisects the track or has been recorded entering from a previous cell; multiple individuals (based on track size) may be scored but presence/absence data per species per cell provides adequate information.
- Transects lengths in the order of 20 km were suitable for recording bilby, predator and competitor activity in arid shrubland habitats.
- Transects can be constructed to provide concentrated coverage for a specific area or developed separately to provide added coverage for a vast area.
- The surface of the transects should be scored for its usefulness as a tracking surface. Cells with poor tracking surfaces can be deleted from the final analysis.
- The proportion of cells showing activity of a species per transect cell sampled per sample period is the desired form of information. Data for a range of species from WNP is presented in **Box 8 and Box 9** in **Volume III**.
- A tracking transect proforma is presented in **Appendix 9**.

2.7.4 Spot-lighting

Spot light counts provide a direct estimate of species density whereas tracking transects and scat transects (see **Section 2.7.5**) provide an index of density. It can be important to link data collected from an index to a direct density estimate because management practices are generally geared to dealing with numbers of a species and not values such as the amount of activity per transect or number of scats collected per month.

Although it is an advantage to have direct estimates of a species' abundance there are disadvantages attached to achieving these data by spot-lighting:

- the accuracy is influenced highly by the skill and alertness of the observer;
- the act of observing can influence what is being observed (Caughley 1980); and,
- visibility of each species differs and actual density must be calculated from the observed density.
- spotlighting is relatively inefficient in terms of time and labour; generally two people in a vehicle are required when counting animals.

Objectives:

- Determine the composition and absolute density of predators and competitors within the release area.

Procedure:

- Spot-lighting can be conducted along tracking transects while driving at approximately 10 $kmhr^{-1}$ using a 100 W beam to search for animals on either side of the transect.
- Animals can be identified through binoculars and their distance from the transect and the cell location should be recorded.
- Density of the animals seen may be calculated using a range of methods described in Caughley (1980)
- The tracking transect proforma (**Appendix 9**) may be used to collect information while spotlighting.

2.7.5 Scat collection

A species' scats can provide information about the individual and its diet. The size of the scat can be used to infer the size of the individual (see **Appendix 1** for the bilby); the constituents of scats may be used to determine where, when and on what an individual was feeding; and, the relative abundance of scats may be used to assess the distribution and abundance of a species.

Bilby scats may be readily analysed and the constituents identified with relative ease. The analysis of predator scats is more difficult and generally involves hair analysis and tooth and bone identification. Hair analysis procedures are described in Brunner and Coman (1974). Analysis procedures and the composition of dingo, cat and fox diets are discussed in articles such as Thomson (1992), Marsack and Campbell (1990), Corbett (1989), Catling (1988), Potter (1991) and Reynolds and Aebischer (1991).

2.7.5.1 Bilby scats

Bilby scats retain their form in an arid environment and can be readily identified and located near diggings or scratchings at feeding sites.

Objectives:

- Collect scats for diet analysis; and,
- to assess the age/size of individuals occupying specific habitat types.

Procedures:

- It is important to note the date, location and collector's name whenever collecting scat material.
- Each group of pellets is best stored in a separate sealable plastic bag and treated as a single sample.
- Where possible collect at least 10 groups of pellets for a particular locality and time.
- Ensure a range of different sized scats are collected if available.
- Scats stored in plastic bags need to be dry to prevent them from becoming mouldy.

2.7.5.2 Predator scats

The scats of dingoes, foxes and cats can be generally differentiated with some experience and reference to guides such as Morrison (1981) and Triggs (1984). These predators often place scats where they can be noticed and in arid areas they can remain intact for weeks. Even places where cats bury their scats became noticeable; they can also become exposed during the surface preparation of predator transects. A measure of scat catch per unit time can be used to estimate relative density. The advantages include:

- scat deposition is probably independent of substrate condition; and,
- in stable, arid conditions scats will accumulate between sample periods;

The disadvantages include:

- differential decay of scats may affect data accuracy; and,
- certain individuals or species may avoid depositing scats along transects

Objectives:

- Collect scats for diet analysis; and,
- infer the distribution and abundance of predators by frequency of scat deposition.

Procedures:

- Collect the entire scat in a plastic bag and label with the date, location and collector's name.
- The number of scats collected along a regularly traversed routes (e.g. a predator transect) may be used as an indicator of relative predator abundance.
- A quantitative measure of predator abundance may be gathered from the number of scats encountered per distance surveyed per sample period.

2.7.6 Bilby diet analysis

The analysis of scat material is an important tool in a bilby release operation and may be used to:

- assess the diet of the species;
- identify the presence of important foods; and,
- establish where and when an individual was feeding.

Scat analysis provides the most feasible method to assess the diet of the bilby because observation of feeding animals is difficult (foods used by the bilby are diverse, often small and frequently located in the soil) and collecting animals for stomach analysis is not appropriate. Additional information about the bilby's diet may be obtained by examining feeding sites; for example, the use of root dwelling larvae is readily indicated by foraging activity at the base of certain shrubs or forbs.

At a release site, a situation may develop where the diet of released individuals (having access to food hoppers and native foods) can be compared to the diet of their progeny (reliant predominantly on native foods). This provides an opportunity to examine how animals fare under different conditions of food availability at the one location. The presence of supplied seed in the scat material (which is usually easy to identify) provides an identifying marker indicating where an animal has fed.

Examination of scat material can be conducted crudely in the field by crushing scats and viewing with a hand-lens or the samples may be stored for a more detailed investigation. Features in the scats such as the amount of sand, the colour of constituents and the presence of supplied seed can be readily assessed. More detailed examination such as the identification of native plant or invertebrate species eaten generally requires viewing the material with a binocular microscope at 6-50x magnification.

Objectives:

- Determine the food items used by the re-established population; and,
- quantify the frequency of foods consumed and establish the relative importance of items.

Procedures:

- For rough estimates in the field, simply crush the scats and examine the material with a hand lens or magnifying glass. Estimate the relative proportions of sand, seed and invertebrate material.
- The procedure used to analyse and quantify the diet of bilbies in a laboratory is more involved.
- To view the scats it is best to select one small pellet or portion of a large one and crush it into a petri dish.

  Add water until the material is evenly suspended and then allow the water to evaporate to leave a film of scat material. The evenly distributed remains can then be examined under 6-50x magnification.
- The information recorded from scat analysis may be summarised using the following methods to allow a ready comparison of results. A proforma for data collection is provided in **Appendix 10**.
- Both the presence and the frequency of prey and non-prey items are important to note. Search each sample for different dietary items and, using an optical grid, record the first 25 identifiable fragments in addition to the number of the unidentified particles and the sand grains. This procedure guards against inadequate sampling of identifiable fragments. Bilby hair incorporated in the scats can be ignored. The categories easily recognised include: sand, seed, spore, bulb, other plant, termite, ant, beetle/grasshopper, unidentified invertebrate, vertebrate and unidentifiable material.
- The frequency of summed plant, summed invertebrate, sand and unidentifiable material in each sample can be used to provide an estimate of the proportion of the scat volume taken up by each category.
- It is also important to note the main or "number 1" food in each sample and develop an idea of the types of No.1 food used at a locality at a particular time. The proportion of samples containing the most common No.1 food provides an indication of the importance of a particular food item at a locality.
- An index of diet diversity (modified Simpsons Index)?can be calculated for pooled samples and a coefficient of similarity may be used to compare the scat constituents between localities (see **Section 4.3.4.2, Volume II**).

2.7.7 Vegetation composition and structure

It is important to monitor vegetation because:

- its composition affects food production;
- its structure can influence the mobility and distribution of species like the bilby; and,
- its composition provides an indicator of site richness and the degree of disturbance.

Information on the composition and structure of vegetation can be obtained by conducting vegetation transects in specific habitats or localities at a release site. See Kent and Coker (1992) and Brower and Zar (1977) for an overview of methods. The presence of certain key plant species will indicate the presence of important plant foods for the bilby. Certain plant species may also indicate the potential for important invertebrate foods to occur e.g. *Acacia* shrub species such as *A. kempeana, A. rhodophloia, A. dictyophleba* and *A. hilliana* at times contain Lepidoptera larvae (or witchetty grubs) in their root stock and these are favoured foods of the bilby.

Objectives:

- To determine the existence of important native foods at a release locality; and,
- describe the structure and composition of vegetative communities at a release site.

Procedures:

- There are a number of methods available to gather information on vegetation cover and species composition. Wheelpoint (Griffin 1989) or step-point measures have been used to enable simultaneous collection of cover and species composition over an extensive area.
- Point transects are those where plant species information is collected at individual points spaced at a fixed distance apart i.e. 0.5 or 1.0 m. At least 500 points should be collected to obtain information representative of a particular area.
- The point transect information may be collected from one transect or several shorter transects placed in quadrats.
- The presence of uncommon plants may have to be sampled by intensively searching quadrats e.g. a 20 m square quadrat.
- The height of the main plant species needs to be recorded and those likely to cause obstruction to the bilby need to be grouped. At the simplest level, vegetative cover minus prostrate plants, small litter and bare ground will indicate an impedance value for the bilby.
- A proforma presented in **Appendix 11** indicates the information useful to record.

2.7.8 Rainfall, geomorphology, fire and herbivores

Vegetation composition and structure (and therefore, food production) are largely dependent on six variables: rainfall, temperature, soil, landform, fire and herbivore disturbance. In reality these variables do not work in isolation. For example, fire frequency is related to the amount of grazing pressure and plant growth; and, soil moisture is related to the amount of rainfall, soil and landform characteristics and temperature, etc.

Our ability to manage and predict changes to vegetation structure and food production is dependent upon understanding the links between these independent variables and vegetation growth. During a reintroduction program we should endeavour to collect quantitative information about these relationships. Because of the lag time in ecological processes (such as the time taken for the growth, maturation and breeding of plants and animals), predictive models of biological activity may be developed with this information to assist in the scheduling of management.

Some of the variables such as herbivory, rainfall, fire and temperature may affect habitat conditions at a site significantly on a temporal and spatial scale; soil and landform variables can be considered relatively stable in time but subject to significant spatial variation. We must learn to sample efficiently and opportunistically to include a full range of possible conditions including relatively uncommon events such as exceptionally high rainfall periods. Any attempt to monitor the effect of one variable requires adequate replication and contemporaneous control of the other variables. Options for intervention or management are generally limited to altering herbivore disturbance and the fire regime.

2.7.8.1 Rainfall and temperature

Objectives:

- Establish baseline rainfall and temperature records at a site to aid the prediction of habitat characteristics; and,
- establish the historical frequency of rainfall and assess the conditions at a release site in comparison with past records.

Procedures:

- Accurate historical rainfall records from properties or towns in the surrounding area may be used to assess the frequency of exceptionally dry or wet periods.
- A number of methods are suitable to summarise these data to indicate past and present conditions (see Sutherland *et al.* 1991):

- cumulative residual graphs;
- rolling average graphs; and,
- centred mean graphs.

- Rainfall and temperature records representative of the area need to be collected during the release preferably with equipment stationed at the site. Daily and monthly rainfall and minimum and maximum temperatures are required.

2.7.8.2 Soil and landform

Soil fertility and structure strongly influence food production and vegetation pattern. The mapping of soil and landform distribution at the release site is therefore, important. This procedure generally involves the use of aerial photography or satellite imagery to draw landsystems and then "ground truthing" of selected sites to confirm the characteristics of the defined systems by field survey.

Objectives:

- Establish the patterning of vegetation at a release locality in relation to soils and landform characteristics.

Procedures:

- Important soil attributes include depth, texture, acidity, carbonate presence, available phosphorous, pedality and coarse fragment size, type and abundance.
- Standard procedures to collect and describe soils and map land systems are provided by McDonald *et al.* (1985) and consistent use of the specified proformas is recomended. Comparison of different systems requires collection of data from at least two independent sample localities in each system.

2.7.8.3 Fire plots

Fire is one environmental variable that may be readily manipulated and managed at a release site. Plots of different fire age may be relatively easy to establish at a release site. These may be monitored over time to determine the development of vegetation in response to fire history, rainfall and temperature and the relative use of the vegetation types by bilby individuals and other species.

Objectives:

- Establish the effect of fire on the plant and animal communities at a release site.

Procedures:

- Fire plots may be established in different areas of a release site. Replicated plots of the each fire age are necessary (e.g. 3 plots recently burnt vegetation v. 3 plots of older vegetation)

- Plots of 0.5 to 1 km^2 provide suitable areas to accommodate vegetation transects and assess the use by animal species although larger burnt plots are better.
- The timing (season), size and intensity of a burn should be recorded for each fire at a release site.

2.7.8.4 Herbivores

Herbivores selectively graze on plants, avoiding those which are least palatable or contain toxic compounds. Prolonged grazing or browsing can therefore, alter the composition of a plant community. The presence or absence of certain plant species within a general area may be used to indicate the degree of grazing disturbance in a community; experimental removal or addition of herbivores involved may be used to examine the effect of a species and if the disturbance can be managed. Because the effect of rabbits and stock are suspected as altering the suitability of habitat of the bilby it is important to examine the influence of these species on plant communities when appropriate. However, the personnel and botanical expertise required to implement an effective exercise is substantial and costly because of the necessary manipulation of the herbivore populations.

Objectives:

- Determine the effect of herbivores on composition and structure of vegetation.

Procedures:

- Methods to obtain the composition and structure of a plant community have been outlined in Section 2.7.6.
- To determine the effect of a herbivore on a plant community requires a BACI experiment with Before and After monitoring of Controlled and Impacted areas (Green 1993; Underwood 1993). Sites need to be monitored contemporaneously where herbivores have been managed or eradicated and where no management has occurred.
- The scale of operation becomes very important as does the placement of monitoring sites; obviously this is influenced by the resources and time available.

2.7.9 Small animal sampling

The approach and methods used in fauna surveys are diverse; Myers *et al.* (1983) provide a broad overview of the principles and problems. Selected procedures to monitor small mammals, birds, reptiles, amphibians and invertebrates are outlined below. It is useful to collect information on these animals because:

- invertebrates form part of the diet of the bilby;
- some share the same food as the bilby;
- some provide alternative prey for predators; and,
- these animals may be used to gauge community richness and favourability of habitat.

A sampling method effective for one species may not be suitable for another; a range may have to be implemented to adequately sample a particular suite of organisms. For example, trapping using metal traps and pit-fall traps i generally necessary to provide a representative sample of small mammal species at a locality because of the different size and attitude toward traps of these animals. Animal ethics and licensing approval will be required if small mammal trapping is conducted.

2.7.9.1 Small mammal trapping

Sherman or Elliott traps are generally only suitable for mammals over 8 g and more effective for rodents than they are for marsupials. However, they may catch the occasional lizard, snake and bird. The bait in traps often attracts ant species which can harm trapped animals.

Objectives

- Determine the presence and relative abundance of small mammals occupying different habitats or localities at a release site.

Procedures:

- Basic small mammal trapping, using for example, Elliott traps baited with peanut butter and oats, may be used to determine the composition of small mammals at a site and changes which might occur with varied environmental conditions.
- Fifty traps per night per habitat type for a minimum of three nights provides an adequate sample and is the trapping effort commonly applied in small mammal surveys. During trapping exercises traps are commonly spaced 10 m apart with 30 m between trap lines.
- The animals trapped will need to be marked if recaptured animals are of interest. A felt-tipped pen provides temporary ear marking lasting a few days; more permanent marking requires toe clipping, ear punching or tagging.
- Care needs to be taken to prevent trapped animals being harmed by heat, cold or attack by ants.

2.7.9.2 Pitfall trapping

Pitfall traps provide a chance to catch mammals, reptiles, amphibians and invertebrates. Their effectiveness depends on the diameter and depth of the pit and the condition of the drift-line wire netting. Some large or agile species may be able to climb or jump out of or avoid falling into the pits. Holes for the pitfall buckets may be difficult to dig in less friable or stony soils.

Objectives

- Determine the presence and relative abundance of small mammals, lizards and invertebrates occupying different habitats or localities at a release site.

Procedures:

- A common design consists of a fly-wire gauze fence 30 m fence long and 30 cm high erected over five buckets (diameter: 290 mm and depth: 480 mm) spaced about five metres apart with two or three pit-fall lines per habitat.
- Leave open for three consecutive days; clear morning and evening, and provide shade above the bucket when conditions are hot and food (peanut butter and oats)and something to hide under when conditions are cold to prevent harm coming to trapped animals.

2.7.9.3 Invertebrate transects

Some invertebrates such as terrestrial beetles, grasshoppers or caterpillars may be counted while walking set transects. This technique is useful to monitor invertebrate species which are sampled ineffectively by pitfall taps (see **Section 2.7.3**).

Objectives:

- Record seasonal changes in the relative abundance of invertebrates along set width and length transects.

Procedures:

- A transect of one kilometre length and two metre width was found to be suitable for monitoring seasonal changes in the abundance of certain species of grasshopper, beetle and caterpillar.
- Transects were walked and the invertebrates seen within the transect were counted.
- Each transect may need to be walked a few times a day on several consecutive days to achieve a representative sample for a particular period.

2.7.9.4 Bird transects

Birds are ideal indicators of the general richness of an area (Reid and Fleming 1993). They are easy to see and excellent books are available for use in their identification (Pizzey 1980; Simpson and Day 1984; Slater *et al.* 1986). However, accurately assessing numbers is somewhat more difficult because the ability of observers often varies greatly in the sighting and identification of birds; the use of standardised search procedures is necessary to make results comparable. A discussion of methods suitable for censusing birds in Australia is provided by Davies (1984).

Objectives:

- Record the seasonal changes in the presence and relative abundance of birds in the general study area.

Procedures:

- For open shrubby habitats a transect of set length (around one kilometre) surveyed within a set time (about half an hour) provides a basic procedure to collect information on bird species presence and abundance.
- The types of birds seen may be divided on the basis of their tenancy i.e. residents, seasonal transients, vagrants, etc.

2.8 Program costs and conclusion

Material costs for a program which consists of two experimental units (the release of 2 x 5 animals) amounts to approximately $15 000. This amount includes expensive items such as the radio tracking gear and an ATV but excludes items such as the geographic positioning system and a hand held computer which are considered useful but not essential to a program. It is assumed access to a four-wheel drive vehicle would already exist. Itemisation of these costs is presented in **Appendix 12**. It should be possible for an individual full-time employee to implement the program and conduct the necessary monitoring. Alternatively, the program could be implemented and monitored by a group of people on weekends once the released animals have settled in to the surrounding area.

It should be stressed that not all the procedures presented in this volume need to be implemented. The decision rules presented in Fig. 2.5 and 2.6 indicte the essential procedures and those of lesser priority.

Finally, the monitoring procedures outlined in this document are, to some extent, still under scrutiny and there may be changes made to improve the efficiency of obtaining information as our understanding of the ecology of the bilby increases. The Bilby Recovery Team will advise on the changes to reintroduction procedures and prerequisite conditions for the release of animals.

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Appendix 1 Bilby condition assessment proforma

Materials required
20 Hessian bags and washing baskets
Scales 2.5 kg and 1 kg
Large calico weighing bag
Callipers
Plastic bags for scats
Scissors
Ear-tags and tattoo ink and tattoo punch

Animal assessment proforma (See Fig. A1.1, A1.2 and A1.3)

Date: Time: Animal I.D.:

Weight:
Head length: Foot length : Hind track length :
Condition: excellent good poor
Hair loss: Jaw lumps and check for presence of halitosis:

Neck ulceration:
Collar circumference:
Collar condition (check for wear and abrasive points)
  Collar fabric and fastener:
  Transmitter moulding:
  Aerial:

Transmitter condition:
  Transmitter no.
  Frequency
  Pulse strength

Female breeding condition:
  Nipples: inverted everted lactating
  No. of nipples everted:

  Pouch young:
    Head size Weight (if independent of nipple)
    Pigmentation
    Pelage
    Estimated age

Scats collected: Yes No
  Scat diameter:

Track size noted: Yes No
  Track width : Track breadth:

Notes:

Appendix 1 (cont.) Diagrams to assist in the correct measurement of body parts, tracks and scats

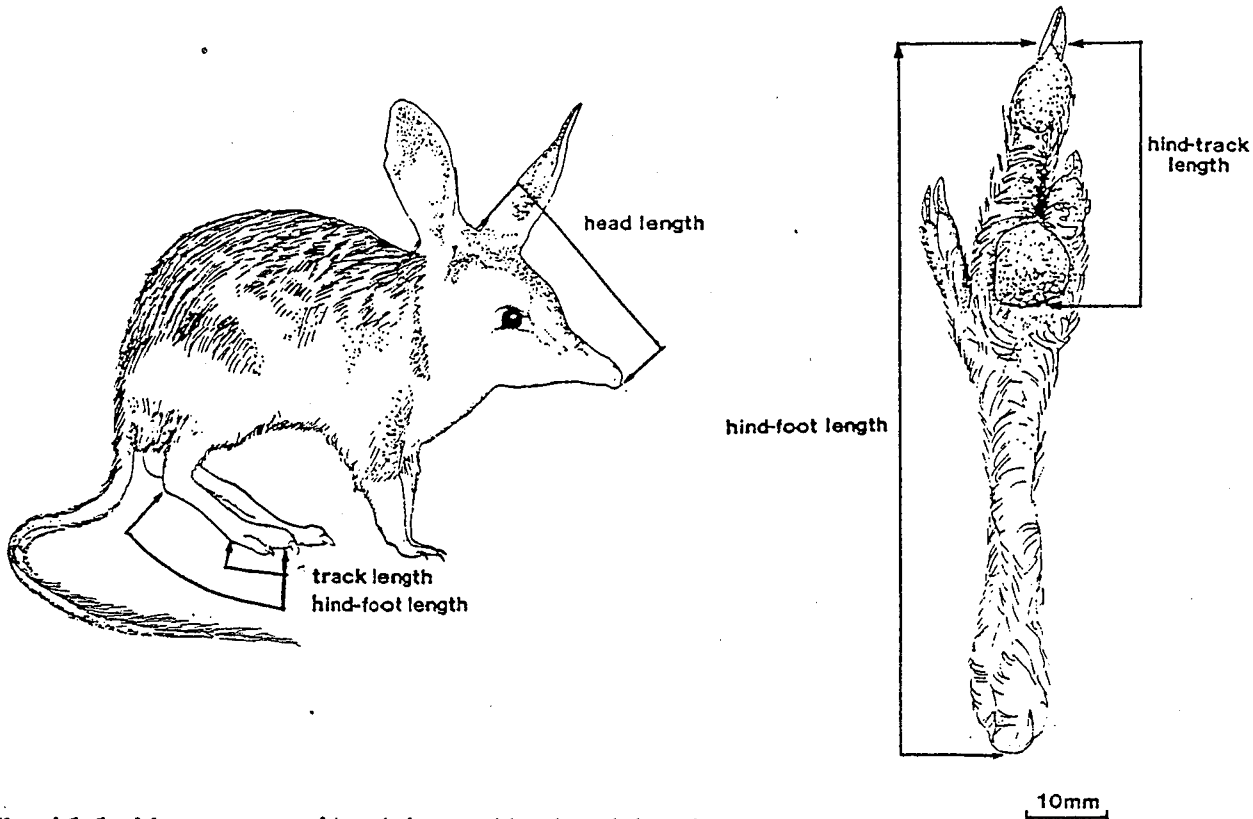

Fig. A1.1 Measurement of head, foot and hind track length

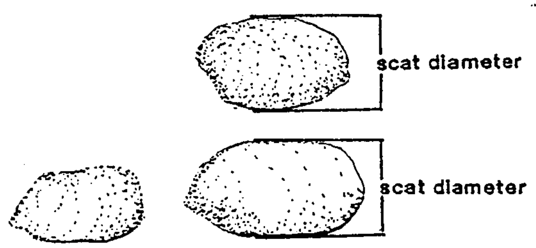

Fig. A1.2 Scat diameter

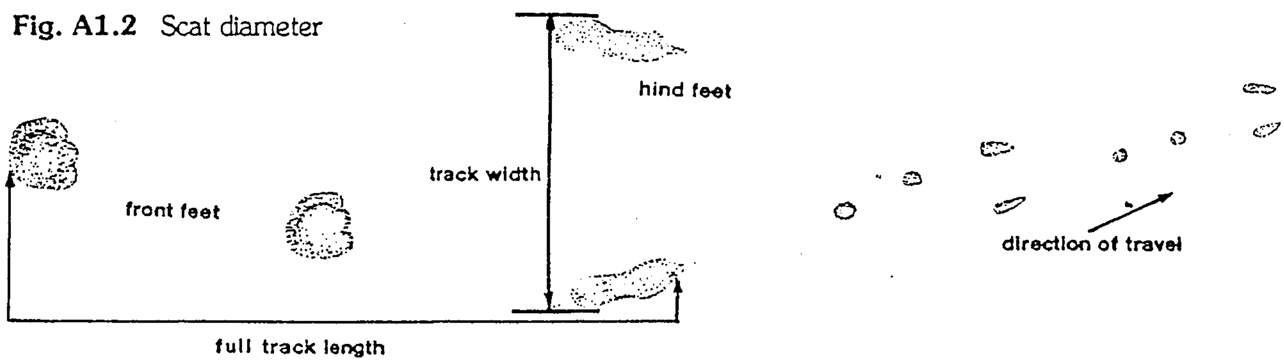

Fig. A1.3 Track width and breadth

Appendix 2a Growth, development and aging of the bilby

The bilby, along with other bandicoot species, has a rapid rate of growth and development compared to other similarly sized marsupials (Lee and Cockburn 1985; Cockburn 1990). All bandicoots are:

- polyoestrous and can potentially have several litters per year;
- produce several offspring in a litter; and,
- take less time to produce and wean a litter than any other marsupial.

Growth

The development of body characteristics in pouch young is shown in **Fig. A2.1a-c**. These along with head length measurements can be used to age the young and estimate their birth and pouch-exit date. Once juveniles leave the pouch, growth rate can vary considerably depending on diet and food availability. Females stop growing at approximately 12 months of age; males continue to grow up to the age of 18 months (**Fig. A2.2**).

Mature males may vary in mass from 1 500 to 2 600 g while females, without pouch young, may fluctuate between 600 and 1 200 g (**Fig. A2.3**). Females containing large pouch young may exceed 1600 g. Males in captivity rarely exceed 2 000 g. Sexual maturity occurs from age 175-220 days in females and from 270-420 days in males.

The size of tracks or scats may be used to indicate the size of an individual. This information is particularly useful in estimating the number and composition of uncollared and unknown animals encountered in the field (i.e. juvenile v. adult; large adult male v. female or small male). Track size is compared with animal weight in **Fig. A2.4** and scat size is compared with weight in **Fig. A2.5**.

Condition of bilby individuals

In the first few months after release animals commonly lose weight. Males may lose 10 percent of their body mass and some may not regain their pre-release weight. There is great individual variability in the capacity to put on weight. For example, one released male remained scrawny throughout its lifetime but survived as effectively as another which attained great size.

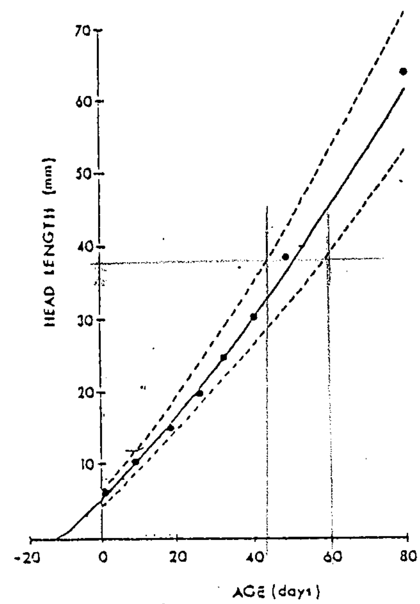

Fig. A2.1a Head length versus age for bilby pouch young (from McCracken 1983).

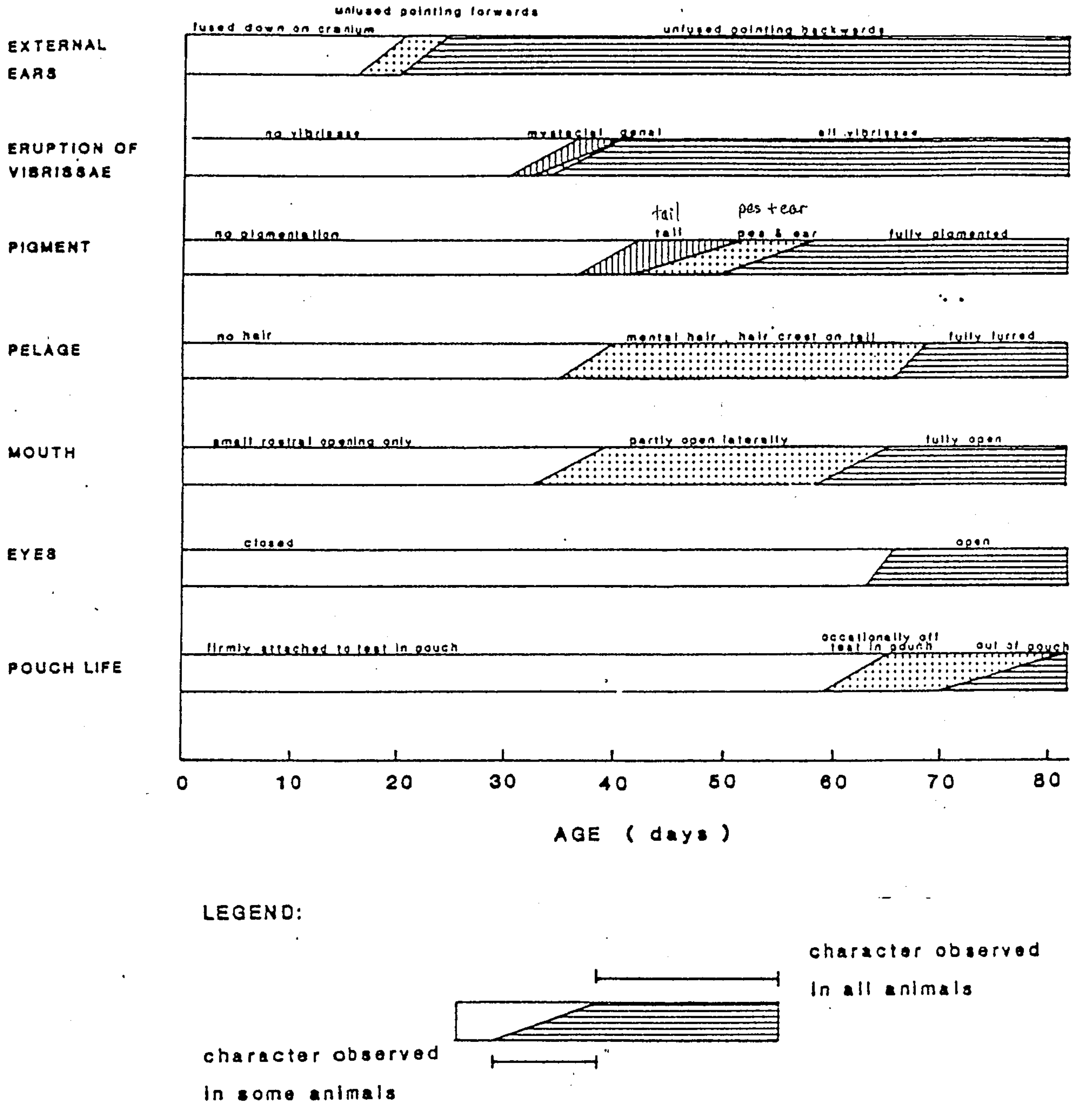

Fig. A2.1b Development characteristics of bilby pouch young (from McCracken 1983).

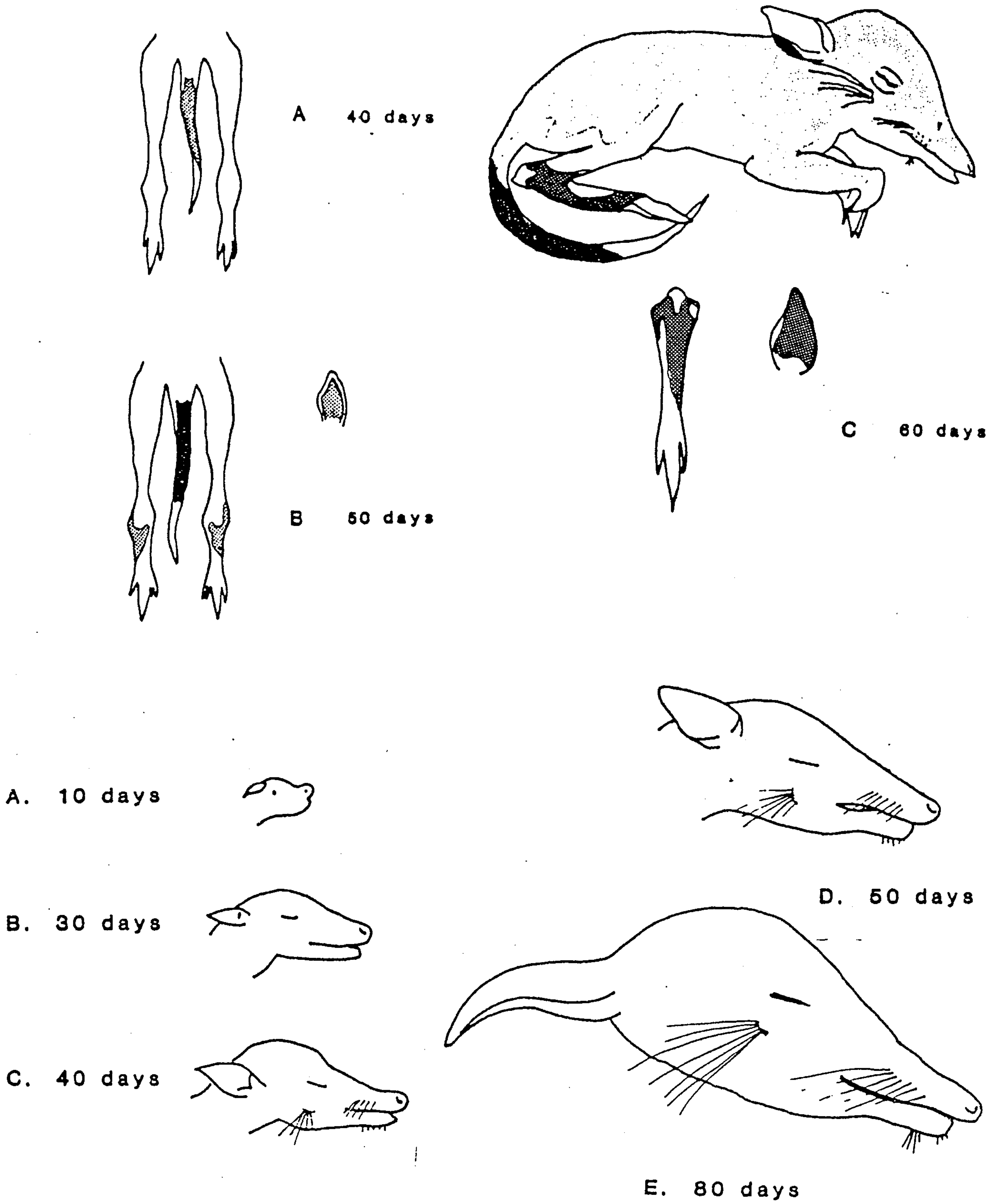

Fig. A2.1.c Progressive pigmentation and mouth opening development in bilby pouch young (from McCracken 1983).

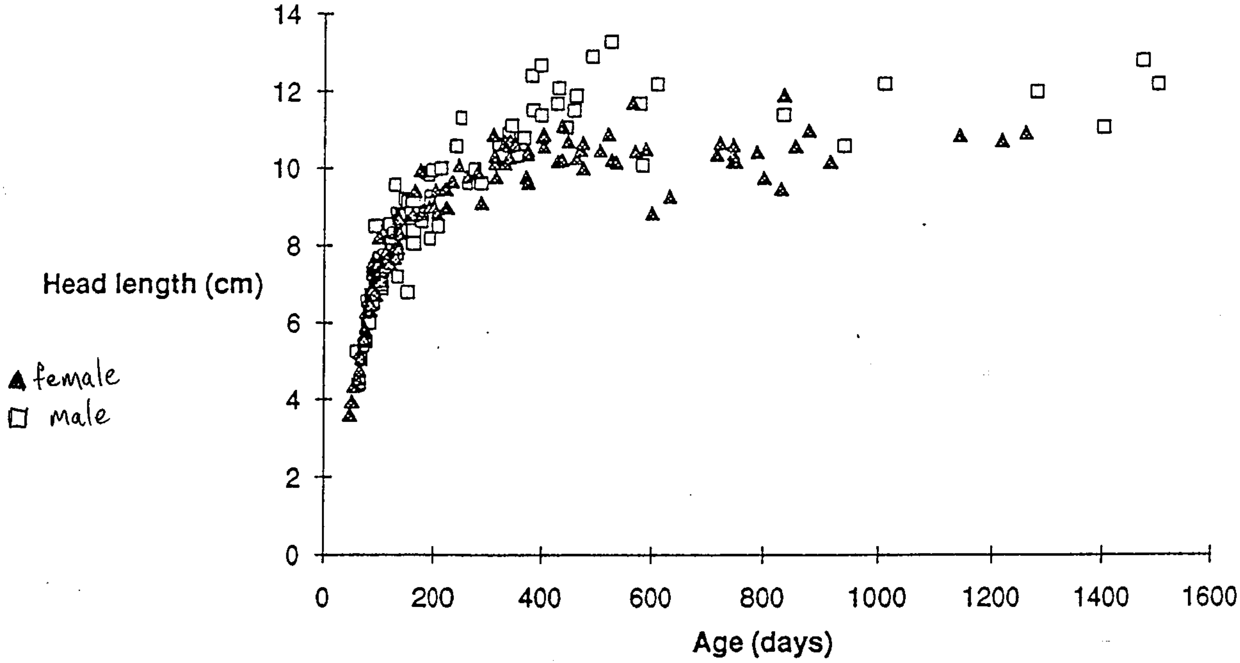

Fig. A2.2 A plot of bilby head length versus age with line of best fit.

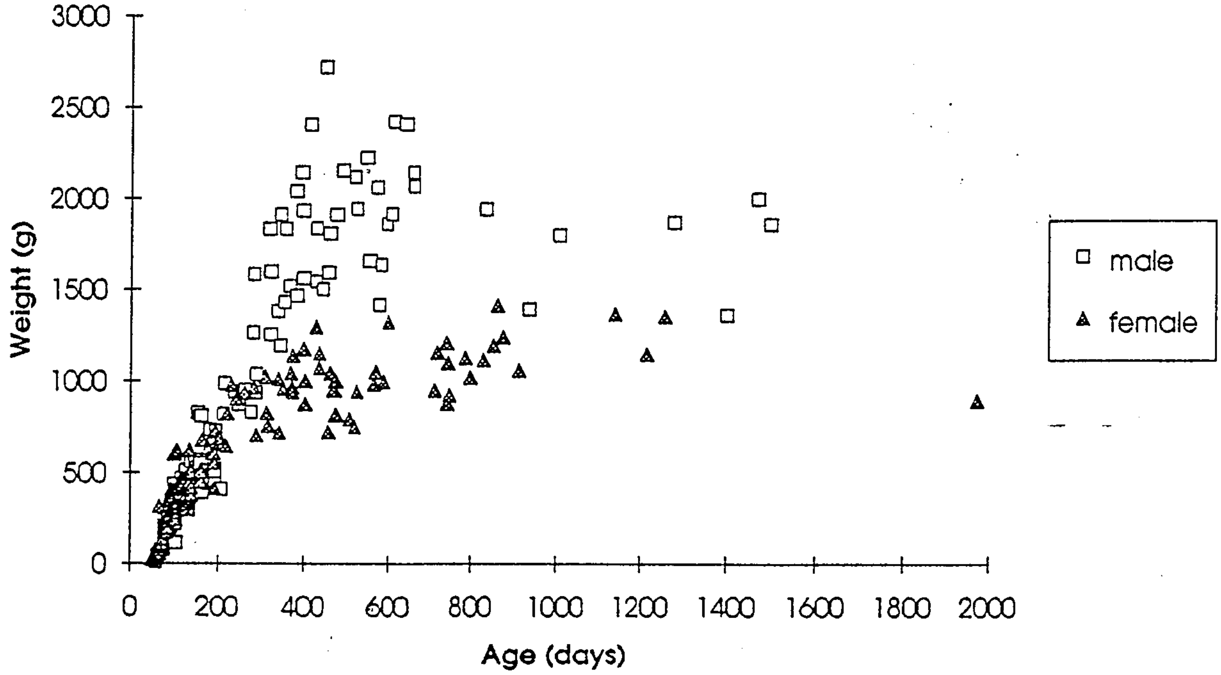

Fig. A2.3 A plot of bilby weight versus age.

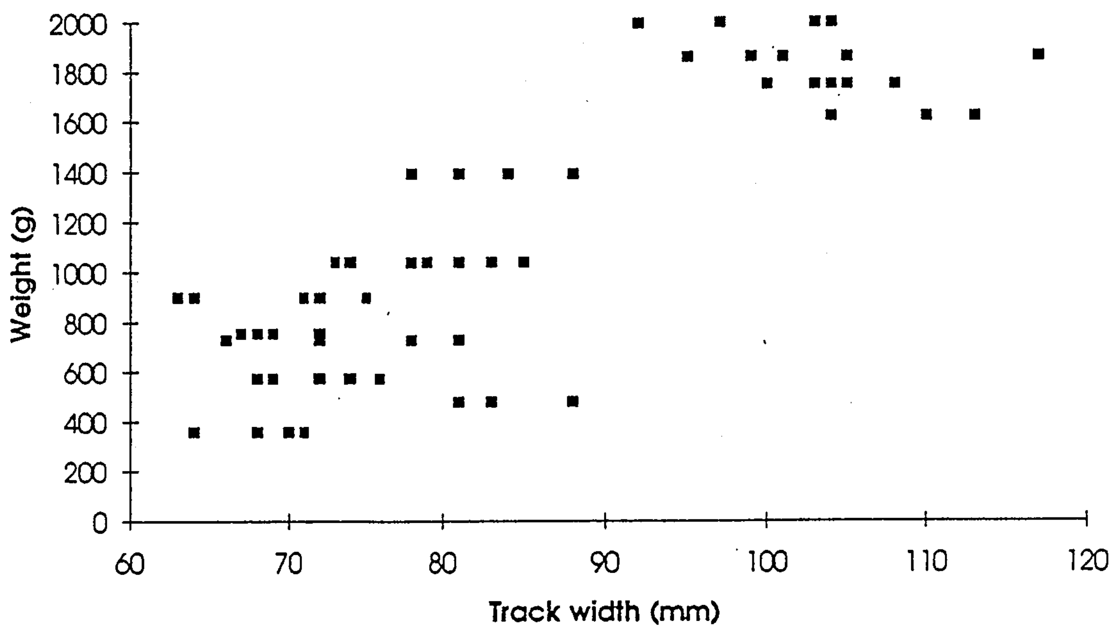

Fig. A2.4 A plot of bilby weight versus track width.

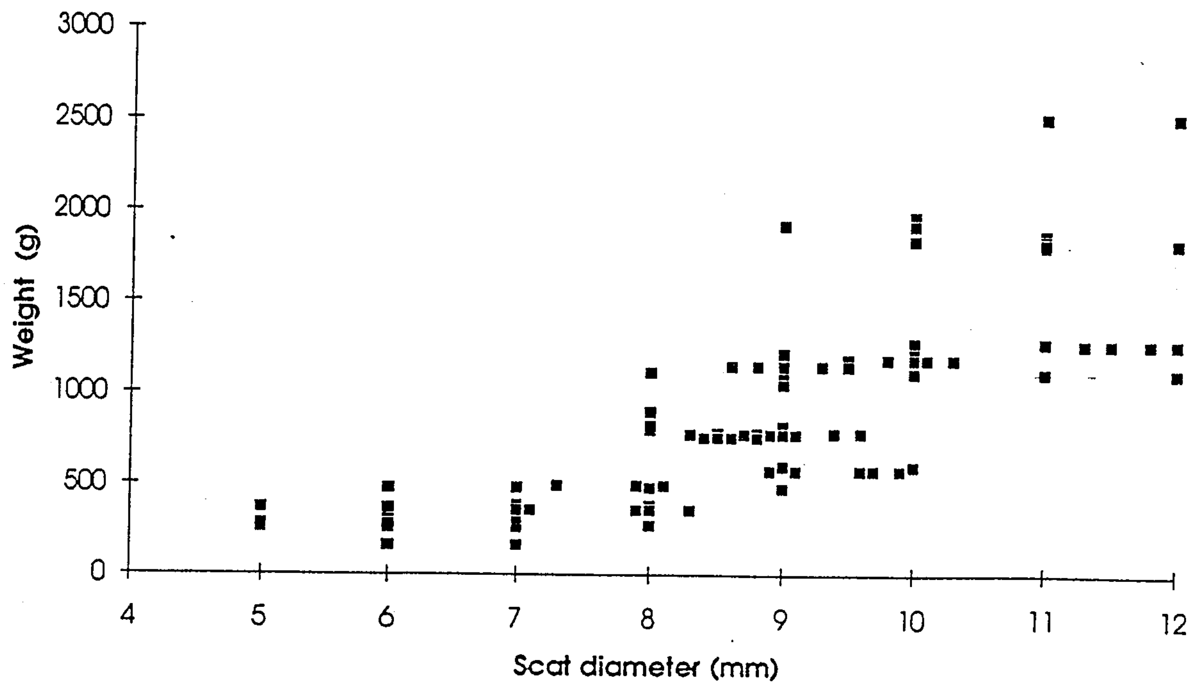

Fig. A2.5 A plot of bilby weight versus scat diameter.

Appendix 2b Fecundity characteristics of the bilby

Oestrous and gestation

Oestrous cycle length is approximately 21 days (range: 12-37 days) and gestation averaged 14 days (range: 13-16) (McCracken 1986). There is no evidence of a breeding season. It is possible for a female to suckle newly born young and young-at-foot simultaneously and, under ideal conditions, maintain a continuous production of young throughout the year.

Pouch life and weaning period

Length of pouch life in captivity has been found to vary between 71-80 days (**Table A2.1**). The length depends to some extent on the size of the female and the number in a litter. After pouch exit the young are cached down the maternal burrow and suckled for a period of approximately 14 days. On emergence, the young are fully independent.

Litter size

Litter size can vary from one to three individuals. Loss of part or all of the litter may occur during the pouch life. The size of the litter when born and the survival of pouch young depends on the size and condition of the female. Average litter size in captivity at AZRI was approximately 1.4; at WNP it was approximately 1.7.

Size, sex and weight of young

Small females (800 g) generally produced small young compared to the young of larger femles (1 000-1 200 g). In addition, individuals of emerging twins weighed approximately 100 g, significantly less than single pouch young (approximately 140 g) in captive bred individuals. However, there was no difference in head length and emergence age of the young.

Sex ratio of emerging captive-bred pouch young in Alice Springs and the animals produced at WNP was close to parity.

Maturation and longevity

Females can conceive and produce pouch young at about the age of 175 days and at a weight of 450 g; however, females do not appear to successfully raise young to independence until they exceed 650 g. Six year old animals have produced young in captivity. Males gain sexual maturity at about age 240 days weighing approximately 850 g. In captivity, longevity can exceed 7 years.

Table A2.1 Pouch life and development characteristics in *M. lagotis*. Values of mean ± standard deviation or range (in brackets) are provided.

Body character	McCracken 1985	Hulbert 1972	AZRI records 1990
Initial pouch exit (days)	(78-82)	(67-68)	-
Final pouch exit (days)	(79-84)	(71-72)	74.8 ± 1.2 (73-76)
Head length (mm)	64.3 ± 0.6	(55-64)	58.9 ± 3.8 (53-65)
Weight (g)	177.2	-	122.2 ± 30.(100-155)

Appendix 2c Social organisation and home range

Bilbies like other bandicoots are largely solitary and nocturnally active. Two females or a male and female will occasionally share a burrow during the day; shared use of a burrow is avoided by two males. Females move shorter distances than males; distances of two kilometres are commonly travelled by males between burrows in one night.

Males and females occupy overlapping home ranges. The home range of males is very large and during a three month period may span 160 ha. Females with access to supplied food may limit their movement to approximately 20 ha. Individuals tend to have core activity areas within a home range; the home range of individuals of the same sex will overlap.

Many burrows are excavated at a locality occupied by bilbies and a large proportion of these are visited each night by individuals giving the impression that they are active and could be occupied during the day. This activity makes it very difficult to predict whether a burrow is occupied by an animal during the day.

Bilby individuals will gather in areas where food is abundant; otherwise several animals are generally found scattered over a large area. Densities may vary from 20 individuals km^{-2} to less than one individual km^{-2}.

Appendix 3 Kill description and autopsy proforma
Adapted from Kenny (1991)

Materials required
Plastic bags
Labels
Callipers
Scalpel
Scissors
Kill description proforma

Kill description protocol

One of the aims of this study is to determine the proximate causes of death of individual bilbies. Identifying the predator responsible for the kill is partly art and partly science.

We have little information to identify kills by predators and are trying to establish key characteristics. We use the known kills to set up the classification, so it is just as important to describe a known kill well as it is to describe an unknown one (see Korn and Lugton 1990).

Collect all remains and label with the collector's name, date, location, transmitter frequency or ear-tag or tattoo number. For each item below, note whether seen or not seen. Measurements are required. Put units beside all measurements.

1. Collector: your name
   Date: date kill found
   Tag number: of bilby if ear-tagged or tattooed
   Frequency: of radio-collar if bilby collared
   Location: distance from a known point, e.g. tagged burrow or transect peg; and/or coordinates from topographical map or GPS.

2. Weather
   What the weather is like at the time of recording and what it has been like previously (to help age the dead individual and provide an indication of why it looks the way it does).

3. Microhabitat
   Are remains under bush or tree, in open, up tree (how high)?
   Distance from bush or tree trunk and measurement of ground clearance of overhanging branches?
   Also give microhabitat for kill and/or cache site if different from where bilby eaten.

3. Tracks:
   Before trampling around the site too much, look for predator tracks in the sand etc.
   Record any footprints.
   How old are tracks? Are they the same age as kill?
   Search area 10 m around remains for kill site, drag marks, beds, scats.

4. Scats:
   Record the location: on remains, beside or on track etc.
   These should each be collected separately in plastic bags and labelled on the outside with the collectors name, date, location, species transmitter frequency or ear-tag.

5. Age of remains:
   Is it dried out in sun, rotting, full of maggots, rained on?
   Note recent weather conditions (wind, sun, rain).

6. Collar:

Note tooth, talon marks, cuts or punctures on collar.
Record if chewed up or if most of heat-shrink part of collar gone.
Watch out for old collars which have been previously marked.
Note if blood, fur stuck to the collar an if the collar is closed or open, or still on.

7. Fur:

Note tufts, large pieces; skin on them or not.
For large piece of skin/fur: size, from what part of body?
What kind of shape is it in? (all mangled and holey? intact with no marks?) Take measurements and orientation of holes in skin.

8. Head:

Note if severed or still attached to body.
What part of head left-how much eaten?
How much (if any) of neck left?
Are neck vertebrae crushed or dislocated?

9. Legs and feet:

How many feet are left - specify hind or forefeet?
Are they attached to body or each other or separate?
How detached - dislocated at socket, bone broken (which bone)?
How much of leg left?
Is the meat eaten off bones or bone eaten along with it?

10. Bones:

Are the bones picked clean of meat?
Are bones dislocated at the joints or broken?
Are the bones crushed or clean breaks (end of bone in many tiny bits and slivers or clean edge).

11. Stomach:

Is the stomach inside the body or pulled out?
-whole or part.
-with intestines or separate.
-just contents.

13. Intestines:

Which parts are left - specify either caecum (thick soupy part) or thin intestines (both large and small intestines are thinner than caecum and hard to tell apart except with close examination).
Are the intestines still inside the bilby or pulled out.
Are the intestinal contents scattered around or smeared on other remains.

14. Other organs:

Check the heart, lungs, liver, kidneys.
Note if present or not, and how much eaten, and where they are.

15. Cache:

Was the body cached
Note the microhabitat of cache - open, under bush/tree etc.
-hole dug (even if just shallow scraping) remains put in and then covered.
-completely covered or partly showing.

16. General appearance:

Are remains scattered around a large area in a big mess (how large an area)?
Are they in neat piles? Describe how much meat is eaten from legs, body, etc.

17. Photograph:

We are trying to obtain photographs of known kills and signs that may help others to identify kills. Record if a photograph was taken, and which frame number.

18. Predator identification and probability rating:

From the signs, we can not always be sure who the predator was so we record "best guesses" based on the evidence found at the kill site.

Probability rating:
0 - unknown
1 - no real evidence of any particular predator but a few signs that suggest one or the other.
2 - most signs indicate a certain predator but still a few inconsistencies.
3 - nothing to positively identify the predator but all evidence consistent with that choice.
4 - known predator seen at kill, identifiable feathers, distinctive tracks.

Even with this "conclusive evidence" for known kills we have to be careful. Since predators have been known to scavenge we may find 2 or even more of the above signs (from different predators) at kill. Interpretation of these signs **must be made with great care**, and it may not always be possible to decipher what actually happened.

19. Comments:

Record anything that may help later in clarifying the information on the card, or that may be added information that does not easily fit into any of the above categories.

20. Diagram:

Draw a detailed diagram (with scale) of everything including the orientation of remains, collar, scats.
Also note nearby bushes, trees, logs etc. in 5 m radius around kill.

Autopsy protocol

These procedures are generally best conducted at a field camp, work shop or lab where the equipment may be available.

1. Date: When the animal was found dead

2. Identification: Tattoo or ear tag number

3. Context of discovery:
   - telemetry
   - trapping
   - other (specify)

4. Fate:
   - predator kill (species)
   - found dead in field
   - trap (specify how)
   - other (specify)

5. Location
   - map coordinates or distance to known point

6. Sex:
   -male or female (this should only be recorded if it can be determined from the carcass)

7. Reproductive condition:
- same as for trapping (see **Section**)

8. Age:
- adult, juvenile or actual age if known.

9. Weight:
- total weight of all remains and record whether the bilby was whole or just partial.

10. Head measurement:
- in females, check for pouch young and if present measure head length of young as well.

11. Examination:
If the animal was not obviously killed by a predator, cut it open and visually examine it for broken bones or internal bleeding and injuries. These could suggest why the animal died. For instance, the animal could have escaped from a predator only to die later due to its injuries. Also skin the bilby, because teeth and claw marks can be noted when looking at the inside surface of the skin, and even more obviously on the body and muscle tissue itself. Record any puncture marks, bruises and broken bones. Measure the distances between puncture and bruise marks. This may tell you what species the predator was.

Collect the following items (if possible). Everything collected should be labelled with ear-tag number or identification number and date:
- kidney
- lung
- stomach
- faecal sample
- long bone
- bone marrow

12. Liver:
- look the liver over for any obvious cysts, discolouration, or parasites.

13. Kidney
- Remove the kidney by cutting it away from the wall of the abdominal cavity and then pulling it out with the mesentery and fat still attached. There may be fat all through the peritoneal cavity. Just grab the kidney with the fat immediately on it and pull it out. Whatever fat comes with it is what you weigh. Remove the mesentery and fat and weigh it. Also weigh the kidney and then freeze it. The quality of fat surrounding the organ is a measure of condition of the animal.

14. Lung:
- Remove and, if entire, weigh it. Freeze immediately. The lungs are analysed for nematodes and other parasites and it is important to try and get a sample from the exterior boundaries of the tissue where they are more typically found. If not entire, collect as much as possible but do not weigh.

15. Stomach:
- Remove the stomach and freeze immediately.

16. Caecum:
- Remove and freeze immediately

17. Faecal sample:
- Collect from the intestines and put in 50% isopropyl alcohol to be analysed for parasite eggs etc. Collect only if you can get discrete scats. About 10 scats are required.

18. Long bone:

- Collect one of the hind leg bones (either femur or tibia), preferably from the right leg and record which bone you collected. The bone cannot already be broken. Break the bone open and remove the fleshy interior. All of the marrow from the bone must be removed as there appears to be a fat gradient from one end of the bone to the other. Contaminated of the marrow with bits of bone or muscle should be avoided.

19 Parasites:

- Record whether present, not visible or unknown.
- The scats, tissue and organs should be examined under a microscope as many of the parasites are quite small.

Appendix 4 Specifications of traps used during the WNP reintroduction program

Bilby traps
Tomahawk skunk trap
Internally opening, spring-loaded door
Single door
500mm x 180mm x 180mm (i.e. 20"x7"x7")
Model No. 204 (Collapsible)
Model No. 105 (Rigid)

Address:
Tomahawk Live Trap Company
PO Box 323
Tomahawk, WI 54487
USA
ph: 715-453-3550

Elliott Trap
Type B, Elliott traps
460 mm x 155 mm x 150 mm
collapsible
10 per box

Address:
Elliott Scientific Co.
Upwey, 3158
Victoria
Australia

Yard Trap

1. Sections of wire mesh 4 m x 900 mm with mesh 12.5 mm x 12.5 mm (or 25 mm x 12 mm) are used. A 300 mm section of the same material is ring fastened to the 900 mm section to form a footing. Fibre glass insulation rods are fixed at the ends of each mesh section to provide vertical support and allow sections to be readily fastened together (**Fig A4.1**).
2. Vegetation or litter must be cleared away to provide an unobstructed placement of the footing mesh which is directed inwards. The footing must then be covered with soil. None of the free edge of the footing should be left exposed.
3. The footing will need to be cut in three or four places to allow adjacent ends to overlap (and prevent buckling) when the upright is curved or angled.
4. Generally, one hole is cut in each 4 m section to allow a Tomahawk or modified Elliott trap to fit securely.
5. Two 4 m sections of fencing are sufficient to enclose a small burrow; three sections, in combination, are sufficient to encircle a well used, large burrow.
6. The trap, once erected, even when using three sections, is self supporting in high wind.

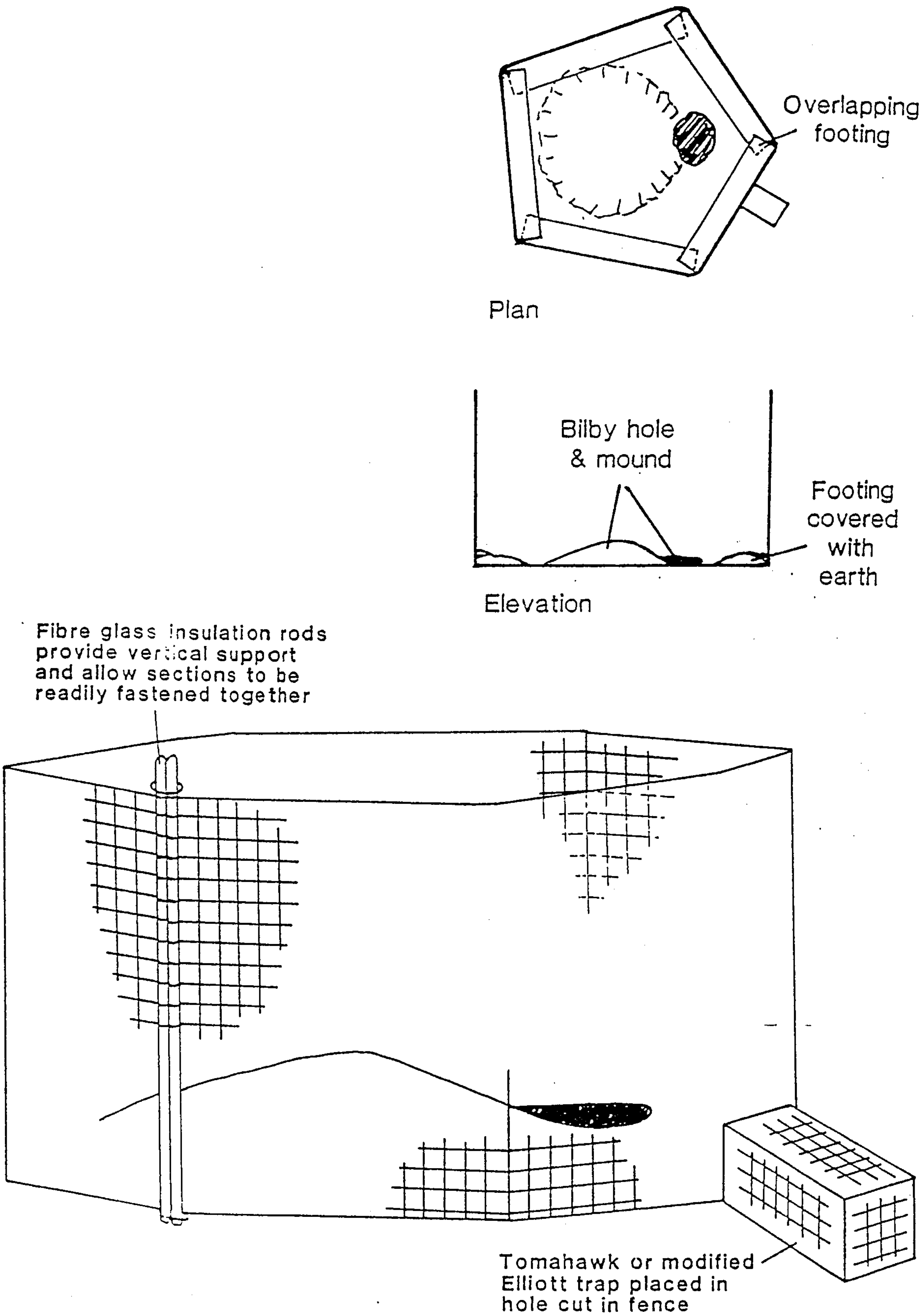

Fig. A4.1 Yard trap design and construction.

Appendix 5 Food hoppers and pen design

Yard traps and pens:
Fence
Chicken mesh
Ring fasteners
pliers
tie-wire
shovels
star pickets

Feeding animals:
seed hoppers
drums for water
plastic hoses
pig drinkers/ nipple feeders

Food hoppers
Food hoppers are used to supply seed to bilby individuals. The design and specifications of suitable hoppers are shown in **Fig. A5.1**. Bilby individuals learn to raise the lid of the hopper with their nose to gain access to the seed. When an individual has finished the lid swings closed automatically and prevents other animals such as seed-eating birds and rodents from taking the seed. Each seed hopper provides seed to feed 3-4 bilby individuals for about one week. Generally two or three hoppers are maintained in each pen in case one malfunctions. Metal plates riveted to the base of each hopper prevent them from being knocked over.

Pen design
The pens are large versions of yard traps. The same materials and basic construction is used except that star pickets spaced every 5 m are used to support the fence with the aid of a strained top wire between corner posts (**Fig. A5.2**).

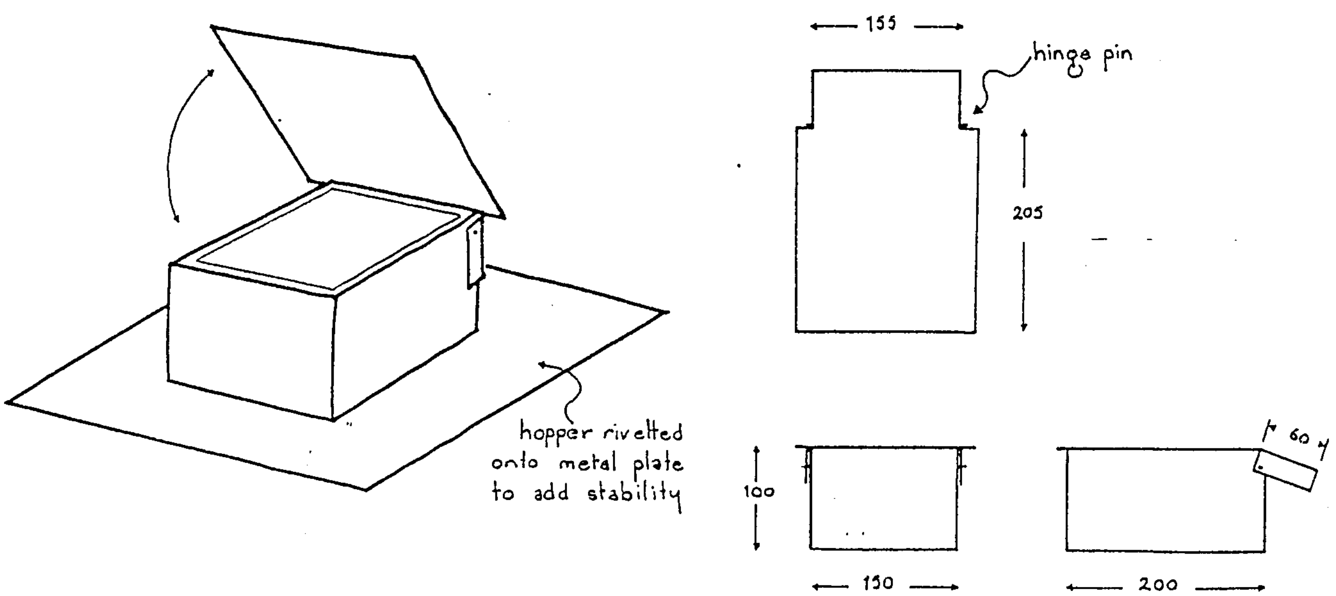

Fig. A5.1 Food hopper design and specifications for the supply of small parrot or budgie seed mix to bilby individuals.

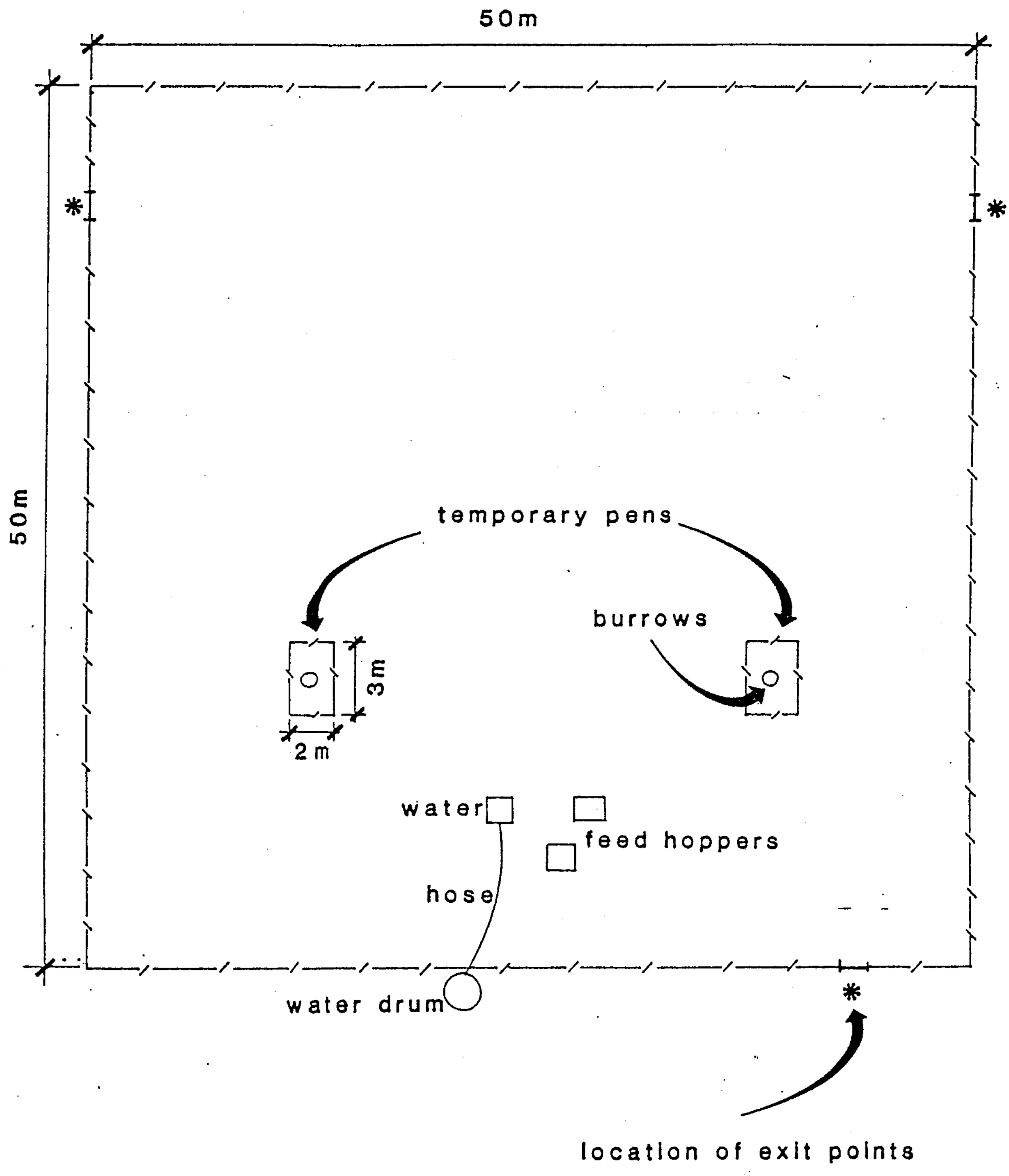

Fig. A5.2 Plan of a bilby release pen showing main components.

Appendix 6 Specifications for radio tracking gear

Telemetry procedures

The principles of radiotelemetry are simple but the application of them to wildlife population studies is often fraught with difficulties. In the simplest case, a radio transmitter which is designed to transmit a signal of specified frequency at about one pulse per second is attached around the neck of an individual. To hear these signals you need to have a radio receiver and an antenna adjusted to the correct frequency. The antenna is directional so that when pointed towards the animal the signal strengthens and away from the animal the signal diminishes. If your hearing is good and the electronics are working you can find the compass line that points toward the animal's current location.

However, many variables can affect the signal strength and its true direction:

- The animal may be moving while you are trying to get a fix on its location and it may move out of range.
- The radio may stop working because of a short in the battery.
- The compass line is estimated incorrectly.
- False signals may bounce from rocks or trees.

The list goes on, and the only way to find out about these problems is to try it out in the field. After several days you will discover the strengths and limitations of radiotracking

The range obtained while radio tracking depends on the strength of the transmitter, effectiveness of the transmitter aerial, the position of an animal (whether above ground or in a burrow), strength of the receiver and the gain and location of the receiving aerial. The transmission range of equipment can be most readily enhanced by increasing the altitude of the aerial and improving the line of sight to the transmitter. Receiver aerials are often placed on masts and located at high points in the landscape for this reason.

Radio transmitters attached to collars are best suited for individuals which have stopped growing; however, expandable or breakaway collars are available for use on juveniles (Soderquist 1993). Transmitters have been glued to the back of some species with some degree of success (e.g. eastern barred bandicoot).

General specifications for radio tracking gear used

Transmitter unit

- Two stage unit including magnetically operated reed-switch
- Frequency range 150.000-150.999 MHz with minimum of 0.020 between individual frequencies
- Pulse rate 40-60 $min.^{-1}$ and pulse width approx. 18 ms
- 3-3.5 V lithium batteries
- Half AA cell for adult collars
- Light flexible whip aerials made from 1.0 mm plastic-coated, stainless-steel tracer wire
- Transmitter and battery encased in water-proof epoxy resin

Collar

- Clear flexible plastic material 8mm width (**Fig. A6.1**)
- Fastened with nylon nuts and bolts
- Heat-shrink material used to fix aerial to collar and direct it towards the back of the animal
- Transmitter fastened to collar with epoxy resign
- Total weight of collar and transmitter unit not to exceed 5 % of body weight of animal i.e. for a female approx. 30 g and a male approx. 40 g.
- Collar circumference will change depending on the age and weight of the individual. **Fig. A6.2** plots the collar circumference used successfully on bilbies against their weight. This graph may be used to estimate the suitable collar size for a bilby of a particular weight.

Receiver and aerial

- Hand-held "H antenna" with 4dB gain

Additional equipment

- soldering iron to use on heat-shrink
- leather strap to slide between collar and neck to protect animal from being burnt during heat-shrink process
- long-nose pliers
- wire snippers
- scissors

Addresses of transmitter and receiver manufacturers

AVM Instrument Company
6575 Trinity Court
Dublin CA 94566
USA

BioTelemetry Tracking
PO Box 187
Norwood SA 5076
Australia

Sirtrack Electronics
Goddard Lane
Havelock North
New Zealand

Telonics Inc.
932 East Impala Ave
Mesa, Arizona 85204
USA

Titley Electronics
PO Box 19
Ballina NSW 2478
Australia

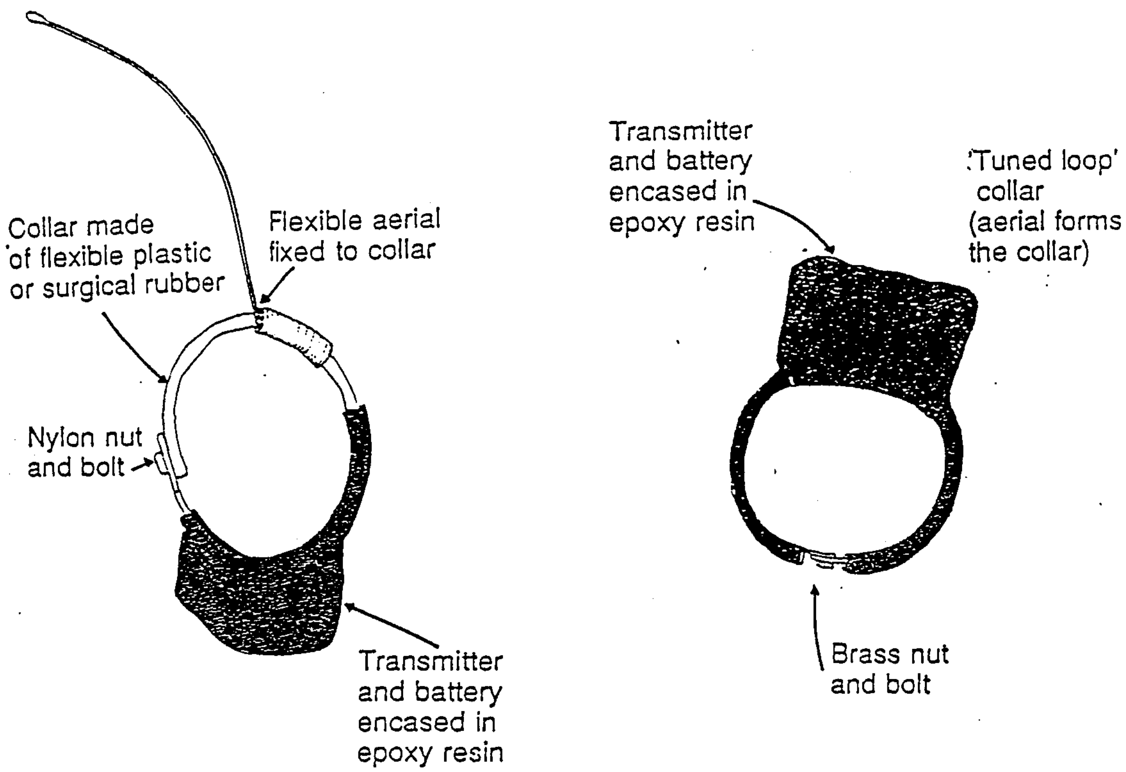

Fig. A6.1 Radio collar designs which were found acceptable for use on adult bilbies.

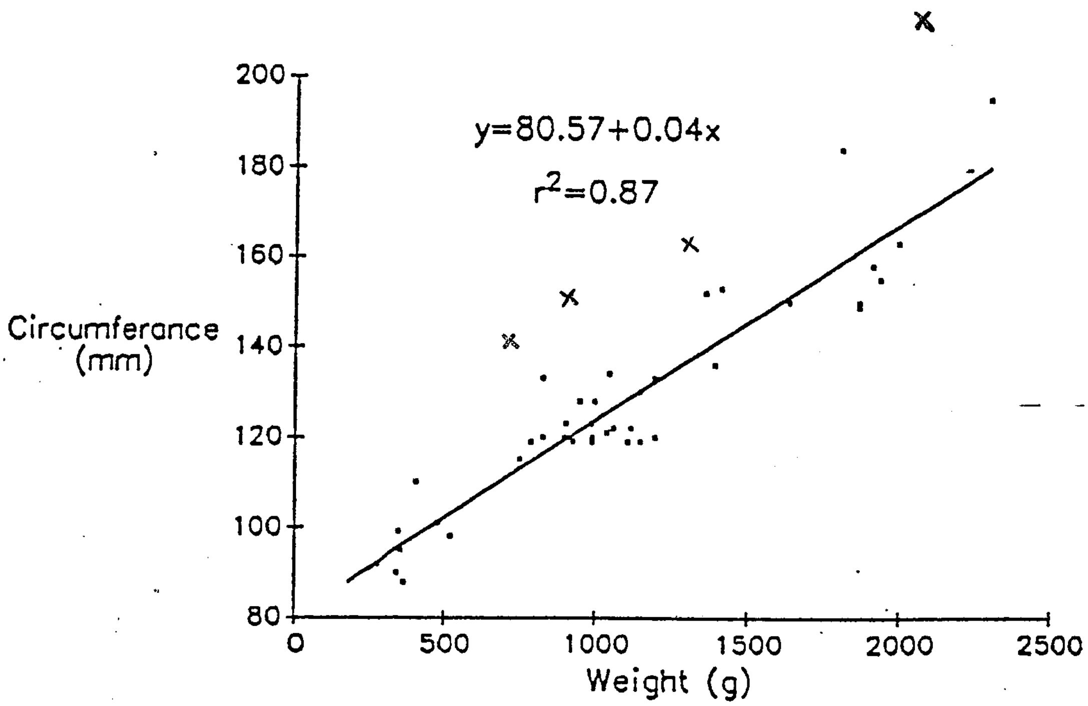

Fig. A6.2 Collar circumference versus bilby weight.

Appendix 7 Bilby activity and location

Protocol

1. The proforma provided below outlines the information of value to collect when radio tracking collared animals or searching for new bilby activity.

2. It is important to record the amount of search effort spent looking for the sign of animals. This includes the area surveyed or distance travelled, the amount of time taken and the people involved.

3. New areas with activity in the form of diggings, tracks and burrows should be noted. An attempt should be made to distinguish whether this activity was made by known individuals or others. Also the age and sex of the individuals using the size of tracks and scats as a guide.

4. Particularly active burrows and those with sign of juvenile tracks at the entrance are important to record.

5. It may be useful to note predator activity and to collect their scats while traversing the sample area.

Bilby activity and location proforma

Date:
Time:
Weather
Rainfall

Bilby identification	Collar frequency	Burrow no. Previous	Current
e.g.			
F94	216.3	95	103
F84	259.6	59	59
.			
.			
M98	680.4	75	201

Sample area and sample intensity:

Predator/competitor sign

Other activity:

Notes:

Appendix 8 Burrow activity monitoring

Materials:
Flagging tape
Metal tags for burrows (individually numbered)
Tie-wire ties for tags
Aerial photos or small scale maps
Geographic positioning system (to map key localities in the absence of map or air-photo characteristics)

Burrow record protocol

1. Make sure burrows are clearly tagged and flagged when located. Using the format suggested on the **Burrow record pro-forma** record the date it was located and when it was suspected of being first constructed.

2. Record a description of the burrow placement (e.g. under log, next to ironwood) which might help in later relocation of the burrow.

3. Record the location of the burrow in reference to a fixed known point nearby or at least two other burrows of known location. For burrows occupied by known animals determine the distance of the burrow to the release point of the individual.

4. In subsequent visits use the **Burrow activity pro-forma** to record the presence of tracks and diggings within a 10 m radius and the type of activity around the burrow.

Burrow record proforma

Burrow no.	Location date	Activity date	Description of location	Vegetation nearby	Nearby burrows	Lat.	Long.	Distance to release
001								
002								
.								
.								

Burrow activity proforma

Date
Recorder
Last rain

		Burrows:			Activity:			
Burrow no.	Date	Collapsed	Open non-act.	Open active	Tracks	Diggings	Nearest act. burrow	Predator sign
001								
002								
.								
.								

Appendix 9 Tracking, animal observation or scat transects

Materials
ATV for tracking
brush or chain drag
4WD for transport
Spotlight, binoculars
Proforma
Plastic bags and labels

Transect tracking protocol

1. Tracking transects provide an opportunity to systematically collect information on the frequency a species is seen and a track or a scat is encountered.

2. Clear transects of tracks and collect predator scats. Resurvey for tracks after 24 hours have elapsed, and for scats within one month.

3. Tracking and spotlighting are generally conducted on two or three consecutive days to establish a number of samples for a sample period.

4. Note distance and direction to animal when a sighting is made during spotlight transects.

Proforma for collecting information on tracks, scats and animal observations from transects

Tracking transect
Date:
Time:
Weather:
Rainfall:
Transect name:
Section:
Observations: Tracks: Scats: Spotlight:

Sector	Cat	Fox	Dog	Bilby	Rabbit	Kangaroo	Other
0-0.5							
0.5-1.0							
1.0-1.5							
1.5-2.0							
2.5-3.0							
.							
.							
.							

Appendix 10 Analysis of bilby scats

Materials
Collected scats
Labels
Plastic bags
Hand lens

Protocol

1. For each scat sample, identify the constituents at the intersections of an optical grid. Continue sampling the grid in a regular fashion until 25 food items have been identified. Note the number of intersection points with sand and unidentifiable matter.

2. Separate seed which is native (nat.) in origin from that supplied (sup.). Seed from a number of native plant species may be found in a scat and these should be identified.

3. Attempt to identify any invertebrates found to Order.

4. Once the 25 points have been collected, scan the sample and note the presence of food items which were not scored by the intersection method.

Scat analysis proforma

Scat batch: Location: Scat size:
Scat no.:
Recorder:
Date:

Point	Seed nat.	sup.	Bulb	Other plant	Spore	Termite	Ant	Beetle	Grashop	Other invertebrate	Other items
1											
2											
.											
.											
25											
Sum											

No. of sand points =
No. of unidentified points =

Scan of sample
Additional items present:

Food items coded above:

Appendix 11 Vegetation analysis

Materials

Wheel-point
Plastic bags for plants
Mobile plant herbarium
Ruler
Star pickets
Hand held computer (Griffin 1989) or clipboard with proforma

Protocol

1. Step-point or wheel-point methods aim to estimate the coverage of vegetation. That is the proportion of ground occupied by a perpendicular projection to the aerial part of plants.

2. Record and code plant cover from different vegetation strata. For example, separate shrub or tree strata cover from the ground strata vegetation cover.

3. Along a vegetation transect, identify each species of plant scored by the point method and record small litter and large litter (i.e. logs). Note the presence of additional plant species not scored by the point method in the sample area. Use a hand-held computer or paper to record point data.

4. Record a typical height of each plant species scored by the point method and its general phenology, i.e. annual/biennial/perennial, flowering/fruiting, growth form: shrub, tree, prostrate, etc as proposed on the **Vegetation characteristics proforma**.

5. For each sample site, the cover of plants with similar structural similarities may be grouped, e.g. spinifex sp.; bunch grasses; forbs etc. and the vegetation cover may be summarised as suggested using the **Vegetation profile proforma**.

Vegetation characteristics proforma

Transect location:
Date:
Recorder:

Species code	Species name	Cover	Species height	Phenology Life form	Growth form	Reprod. form
.						
.						
.						

Vegetation profile proforma

Site	Bare ground	Small litter	Prostrate forbs	Open ground	Forbs	Bunch grasses	Spinifex	Ground cover	Shrub cover	Tree cover
.										
.										
.										

Appendix 12 Material costs

Note:

- • indicates not included in sub-section or total price estimate
- # indicates an option (usually more expensive) and not included in the sub-section or total price estimates

Item		Unit price	Quantity required	Price
Animal condition and diet assessment				
Hessian bags		$ 2.00	20	$40
Washing baskets		$ 7.00	10	$70
Scales				
1 kg	(Pesola)	$80.00	1	$80
3 kg	(Pesola)	$80.00	1	$80
Calico Bags				
300mm x 200mm (per 100)		$ 30.00	1	$30
450mm x 300mm "		$ 65.00	1	$65
Callipers		$ 17.40	1	$17
Plastic Bags				
75mm x 100mm seal top		$ 1.96		
Ctn x 10pkts x 100 bags		$ 19.58	2	$40
Scissors				
small		$ 4.00	1	$4
large		$ 9.00	1	$9
Hand Lens		$20.00	1	$20
Tattoo Ink	per 200ml	$150.00	1	$150
Tattoo Punch	complete set 8mm	$115.00	1	$115
Tackle box		$21.00	1	$21
Sub-total				**$741**
Traps				
Tomahawk (skunk trap) collapsible + shipment		$37.50	20	$750
Type A Elliot Trap (per box of 25)		$ 270.00	4	$1 080
Type B Elliot Trap (per box of 10)		$ 360.00	1	$360
Sub-total				**$2 190**

Pens and Yards

Material for two pens			
Wire netting			
(50 m x 900 mm x 25 mm hex mesh)	$92.00	12	$1 104
Ring fastener pliers (Maspro)	$18.40	2	$37
Ring fasteners (1000 per box)	$ 10.00	2	$20
Pliers	$8.00	2	$16
Fence straining wire (200m x 3 mm)	$75.00	2	$150
Star pickets (1.5 m)	$ 5.00	80	$400
Plastic water drums (25 litre)	$ 15.00	2	$30
Plastic hose	$ 16.95	2	$34
Pig drinkers	$19.00	2	$38
Seed hoppers	$50.00	4	$200
Material for six yard traps			
Weld mesh			
(50 m x 900 mm x 12.5 mm x 12.5 mm)	$250.00	1	$250
Fibre glass (1 m) insulator poles	$3.00	12	$36
Sub-total			**$2 315**

Radio tracking

Collars and transmitters					
	Biotelemetry	TX-TP -4-V	$165.00	20	$3 300
#	Telonics	MOD-080	$265.00 US		
#	Sirtrack		$280.00 NZ		
Receivers and antenna					
	Biotelemetry	RX3 receiver with scanner	$1335.00	1	$1 335
		2 EY hand-held antenna	$175.00	1	$175
#	Telonics	TR-2 receiver with scamnner	$2365.00 US		
		H antenna	$95.00 US		
Additional gear					
Heat shrink (assorted sizes)			$20.00	1	$20
Soldering iron (12 volt)			$25.00	1	$25
12 volt battery (rechargeable)			$45.00	1	$45
Long-nosed pliers			$10.00	1	$10
Sub-total					**$4 910**

Field monitoring

All Terain Vehicle for tracking transects				
	2WD	$4500.00	1	$4 500
#	4WD	$6000.00		
Flagging Tape	Plain colours (75m x 25mm)	$ 2.05	8	$16
Aluminium tags				
	75mm x 38mm x 1mm/100	$ 17.40	4	$67
Tie Wire	100m x 1.25mm	$ 6.15	2	$12
Wire snippers		$6.00	2	$12
Spotlight - 100W		$120.00	1	$120
Binoculars 8 x 35		$ 70.00	1	$70
Geographic positioning system (GPS)				
#	Sony	$2000.00	1	
#	Magellan	$5000.00		
Hand Held Computer				
#	HP100LX	$1200.00	1	
#	Sharp 3000	$2000.00		
Sub-total				**$4 797**
Total				**$14 953**

Glossary: terms and concepts

Individual

The performance of individual animals collectively constrains the dynamics of the population. The inherited (genetic) make-up of an individual predetermines its capacity for reproduction, rate of feeding and digestion, movement and ability to occupy habitat. An individal's capacity to survive and reproduce is also influenced by its learnt behaviour from exposure to stimuli. Animals bred in captivity can develop different behavioural and physiological traits to wild-bred congeners (Stanley Price 1989; Ralls 1993).

Population, subpopulation and metapopulation

The term population can be used to refer to all the individuals within a species. A population may be made up several distinct groups or subpopulations which exist in isolation. In this sense, individuals released at a particular locality, if no other individuals exist, will form a subpopulation and will add to or reinforce a subpopulation if individuals already exist. The interchange of genetic material between some subpopulations may be prevented because of barriers or separation distance. A metapopulation exists if genetic material can flow between subpopulations .

Fecundity

The average number of young produced per litter by individuals of a specified age coupled with the average number of litters produced in a specified period is used to formulate a fecundity parameter. It may be possible to calculate the fecundity for both males and females of a species if mating history or genetic lineage can be determined.

Demography

Demography is the study of birth and death processes which determine the age structure of a population and the rate of change of the population size. The fecundity and the survival probabilities of individuals of a certain age are the main properties used in demographic analysis of a population.

Environment

The environment consists of the physical conditions as well as the other species that a population must interact with to obtain food, shelter and to reproduce. The environment effect a species directly as in a predator/prey relationship; or, indirectly through changes in the availability of a common resources such as during a drought or through competition. The environment may be seen as having elastic and plastic properties. Components of the environment able to resist or tolerate environmental fluctuations may be considered elastic. Plasticity is evident when fragmentation or degradation result in the permanent or long-term loss of system properties. The term "habitat" is used synonymously with "environment".

Experimental versus observational data

Ecological data may be viewed as a product of either an experimental or observational approach. Ludwig and Reynolds (1988) define each. An experimental approach presupposes that the community is amenable to experimental manipulation. That is, we can divide the community into replicate portions on which various treatments and controls can be imposed (see Armstrong *et al.*. 1994). Therefore, any differences detected in measured responses can be attributed to the experimental treatments.

On the other hand, using an observational approach, we make measurements on the community over a range of conditions imposed by nature rather than the researcher. This leaves us with two alternatives:

- to study different samples obtained at the same time but under different conditions (e.g. sampling of males and females or different habitats); and,
- to study samples at the same place but at different times (e.g. samples taken during summer and winter or wet and dry years).

Both experimental and observational approaches provide us with comparative data. The data are used to develop models or to search for contradictory instances to refute an hypothesis (Underwood 1990). Sequential sampling examines whether a population responds as predicted to a set of environmental conditions.

Models

Models are formulated as an aid to thinking, to help us speculate or to provide explanations (Underwood 1990). They can be merely a collection of concepts to form a "sketch" of what is thought to be happening or something more complex and mathematically explicit which might help one test a hypothesis or predict an outcome (Starfield and Bleloch 1986). In this document we use models in the following ways:

- to provide statements to explain a set of observations;
- to develop a line of reasoning in a process which involves making a series of decisions; and,
- to combine the data and variables in a formula which may provide a realistic account of the main processes involved and outcome of events.

Hypotheses

In ecological science, hypotheses are frequently mentioned, for example we may propose "Increased predation pressure is preventing recolonisation of habitat". Null hypotheses are reference points against which alternatives should be contrasted. Tests have meaning when they are made against an *a priori* null hypothesis (H_o) which can never be proved but can be rejected with known risks of being wrong in doing so. Green (1979) provides a set of rules for the formulation of null hypotheses:

- Let purpose generate a question, and let the null hypothesis be the simplest possible answer to the question consistent with the evidence.
- A null hypothesis must be stated in a way that is testable and falsifiable. There must be possible outcomes that necessitate each of the two possible decisions: accept H_o or reject H_o.
- The null hypothesis entertains the possibility that a process has not occurred or that a change has not been produced by a cause of interest; in statistics the H_o is frequently "nothing is going on". In our previous example a possible null hypothesis might be: There is no difference between the growth of a reintroduced bilby population in an environment which has had predator abundance reduced and a reintroduced population in an environment that has received no treatment for predators.
- If H_o is rejected as being too improbable then the alternative hypothesis H_a should be the hierarchically next more complicated explanation.

The strength of hypothesis tests can be increased by multiple independent tests of the same hypothesis and by experiments.